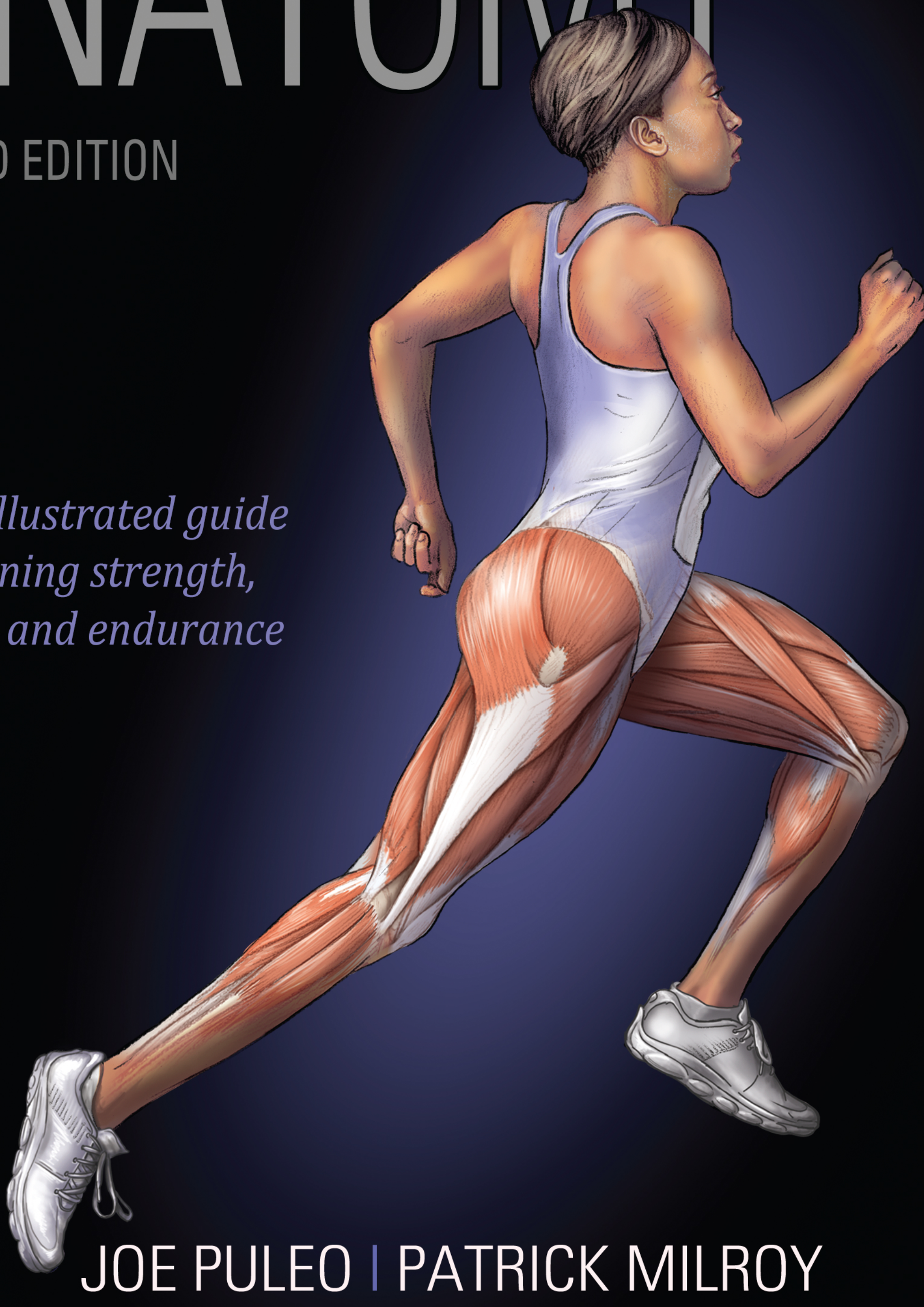
RUNNING ANATOMY

SECOND EDITION

Your illustrated guide to running strength, speed, and endurance



JOE PULEO | PATRICK MILROY

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Joe Puleo

Patrick Milroy

HUMAN KINETICS

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For my son, Gabriel Puleo; may you reach the finish line of the mile in less than four minutes.

In memory of Karl Castor and Art Aubert; thank you for showing me how to love running with all I've got.

Joe Puleo

CONTENTS

PREFACE

Running Anatomy will educate you about how and why the human body works as it does during the movements involved in running. By detailing the mechanisms of movement through illustrations, the book shows, in a simple format, what happens when your body engages in running. More specifically, it explains how and why movement is produced through interaction of the bones and the soft tissues (including muscles, tendons, ligaments, fasciae, blood vessels, and nerves), as well as what you can do to help you reach your personal running goals. This new edition also addresses how running performance is affected by the brain.

The illustrations presented in *Running Anatomy* will help you understand the anatomy involved in running—in particular, how bones, organs, muscles, ligaments, and tendons work to move the body. The text of each chapter explains the function of the body parts shown in the illustrations. The anatomical illustrations that accompany the exercises are color coded to indicate the primary and secondary muscles and the connective tissues involved in each exercise or running-specific movement.

Primary muscles   Secondary muscles   Connective tissues

After detailing how the body functions when running, we present ways to strengthen the body through specific exercises designed to enhance performance. The exercises included in the chapters devoted to specific parts of the anatomy will help you improve your running performance; they will also help you avoid injury by eliminating anatomical imbalances that often occur naturally but are exacerbated by the muscular–skeletal demands of running. Finally, the chapters addressing current topics in running will help you make well-informed choices about exercises, training, and gear.

Injuries often occur as a result of repetitive movement, but understanding how and why the human body moves as it does offers you a simple way to enhance your performance and prevent injury. The ultimate goal of *Running Anatomy* is to help you create a strength-training program that is logical, easy to use, and effective at improving both your running performance and your overall running experience.

Running better does not always mean running faster. This book will help you complete your runs in a more relaxed manner and reduce the incidence of injury or pain caused by running. As a result, you will be able to look back on your completed runs with greater pleasure—and look forward to your next outing with positive anticipation!

ACKNOWLEDGMENTS

The writing of the second edition of *Running Anatomy* was accomplished with the diligence of the editorial team at Human Kinetics including Tom Heine, Michelle Maloney (a second go-round), Cynthia McEntire, and Ann Gindes. Thank you to my beta-readers, Major Christine Taranto, USMC and Dr. Jason Friedman, MD for helping me organize and clarify my writing, specifically chapter 2.

For approximately 30 years, I've attempted to master the art of running coaching. A deep appreciation goes out to all my coaching colleagues, training partners, fellow competitors, and athletes I've coached. Thank you.

Special thanks goes to my co-author, Dr. Patrick Milroy, for his professional acumen, top-notch writing skills, and willingness to collaborate with me. Finally, the biggest shout out of them all—to my family. Jen, Gabe, Dylan, Anna, Sydnee, Sophie, and Victoria, thank you for sharing me with this project.

Joe Puleo

My writing skills were developed through the advice of various editors of *Runners World* (UK), for whom I was the medical adviser for 25 years, and with the help and encouragement of the staff at Human Kinetics, without whom this project would never have gotten off the ground. My knowledge of anatomy was founded at Manchester University and my love of sport and running in particular gave me the impetus to complete this book.

I could not have completed this project without the love and understanding of my wife, Clare, and the support of my family and friends, many from the running world.

Dr. Patrick Milroy

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1

THE RUNNER IN MOTION

Haile Gebrselassie once said, "Without running there is no life!" This joy in running is shared by millions around the world; indeed, it hurdles the barriers of language and culture. Therefore, a stranger abroad need only change into running clothes and running shoes and find a trail or path in order to meet kindred spirits who enjoy life with the same enthusiasm.

Running also ranks highly among ways to combine pleasure with health promotion. As civilization has progressed, people's need to run for survival—whether in hunting or in escaping from a predator—has been tempered by the development of new skills. And the typical human can now enjoy leisure time in a way that the majority of our ancestors would have found impractical and quite possibly fatal. Thus, whereas running used to be a matter of life and death, human social development has enabled it to take on a new character as an expression of human competition, of socialization and sociability, and of scientific experimentation and development. In addition, running is probably the most natural form of exercise. It involves neither aggressive nor antisocial behavior and requires no expensive equipment; therefore, it can be enjoyed by any able-bodied human.

Although the practice of running stretches back many thousands of years, it is only since the late 1970s that an entire industry has developed around running as a sport. In this short epoch, various factors related to running—such as clothing and shoes, the effects of diet on physiology, and the effects of environment and running surfaces—have been subjected to research, experimentation, development, and review. As a result, in much the same way that our predecessors' lives were transformed by the coming of the "iron road" of the railway some 200 years ago, running has now entered the everyday lives of millions of people and, with very few exceptions, provided them with substantial benefits.

The factors that affect the performance of a runner are complex and countless. This chapter focuses in particular on the ways in which runners are affected by anatomy and physiology. More specifically, it addresses the characteristics and physique that produce success in running and considers the makeup of the perfect runner, if such an individual could ever exist.

ANATOMY

The word *anatomy* can be taken broadly to describe the structure of the body. Of course, most of us would like to take pride in our bodies, and the quest to be fit has enabled the business of fitness to become a billion-dollar industry. If we choose not to exercise when we are physically capable of doing so, then we pass up a chance to benefit our health. However, fitness should not be defined in terms of how closely we approach a physical model of perfection. To a significant degree, our body shapes lie beyond our control. For instance, our height is largely genetically determined; nothing we do, aside from achieving good nutrition, will influence it. At the same time, both the appearance and the physical makeup of the human body can be altered through training, regardless of one's starting point. A trained body will be characterized by definition of muscle and skin and by improved performance, if those are the training goals.

If it is your aim to use running, as many do, to improve your body shape, then your results will depend both on how much you run and on what type of running you perform. If your aim is to lose weight, it may take several months of running four or five times per week before you see a clearly visible change, though weighing yourself will reassure you that change is happening.

Running can also affect how you feel. In fact, a lot of scientific evidence shows that running releases chemicals that improve mood and self-confidence. Here again, this effect does not happen overnight; however, if you get into a regular running habit, you will probably experience these benefits sooner than you notice the body-toning effects. As with all worthwhile improvements in life, you will not make these advances without effort, some difficulty, and occasional setbacks. As Theodore Roosevelt said, "Nothing in the world is worth having or worth doing unless it means effort, pain, difficulty."

EVENT-SPECIFIC BODY CHARACTERISTICS

If you attend a track-and-field meet, you can probably guess which runners will compete in which events simply by looking at their physiques. Sprinters, for instance, are often so physically developed that they appear muscle bound. In contrast, those who run the 400-meter to 1,500-meter events become progressively less well built and smaller in stature as the distance increases. Finally, long-distance runners can seem unnaturally thin or even undernourished, though that impression is belied by their race performance.

The fact that we can match body types with events in this manner illustrates that training for different events produces different structural responses in the body. All of the runners have trained for competition, but they have done so in different ways. Distance runners have pounded out many miles—some fast, some slow, and some up hills—on trails and roads, and to a lesser degree, have incorporated track running and resistance training. Sprinters and middle-distance runners, on the other hand, have emphasized track running with weightlifting, gym drills, and other favored exercises to bring their bodies to the required peak. Some middle distance runners (800m to 1500m) also incorporate significant aerobic running, up to 50 to 60 miles per week. Of course, this degree of specialized training may not be necessary, or even desirable, if you are running for your own pleasure rather than for competition.

Your anatomy is governed by the rules of evolution, which broadly state that if you use your muscles then they will develop to cover that use. If, on the other hand, they are left in disuse, they will wither. However, the contours of your body are shaped not only by muscle but also by variably thick layers of fat. As you train, fat is used as a source of energy, and the layers are thinned, though not equally or symmetrically—as those who have tried to spot-reduce have found out. Fat never seems to disappear first from the parts where you most want it to!

RUNNING GAIT CYCLE

How do humans run? Is running just a faster version of walking? Is there a proper running form? Can I improve my running form? If so, how? Runners often pose these questions to running experts, such as doctors, researchers, coaches, and experienced fellow runners. The answers are complicated, but the questions are answerable with a little knowledge of exercise science.

The following subsections provide a basic understanding of the body parts involved in running, the biomechanics that engage and disengage key parts of the anatomy, and the kinesthetic results of initiating the running motion. Accordingly, the drills included in this chapter help runners perfect their running form by fine-tuning the gait cycle.

Running can be understood by analyzing the gait cycle (figure 1.1). Unlike walking, which is defined by having both feet simultaneously in contact with the ground at one point during a cycle, running is characterized by having both feet *off* the ground (the double float) at one point during a cycle. A cycle is defined as the period beginning when one foot makes initial contact with the ground and ending when the same foot recontacts the ground.

The two phases of the gait cycle are the stance, or support, phase and the swing phase. When one leg is in the stance phase, the other is in the swing phase. The stance phase is marked by the foot's initial contact with the ground (foot strike), midstance, and propulsion. The swing phase begins with the float, which morphs into the forward swing, or swing reversal, and finishes with the landing or absorption, thus beginning the next stance cycle. In figure 1.1, the right leg is in the stance phase (making contact with the ground) and is engaging the tibialis posterior and the flexor hallucis longus. The left leg is in the swing phase, preparing to make contact with the ground.

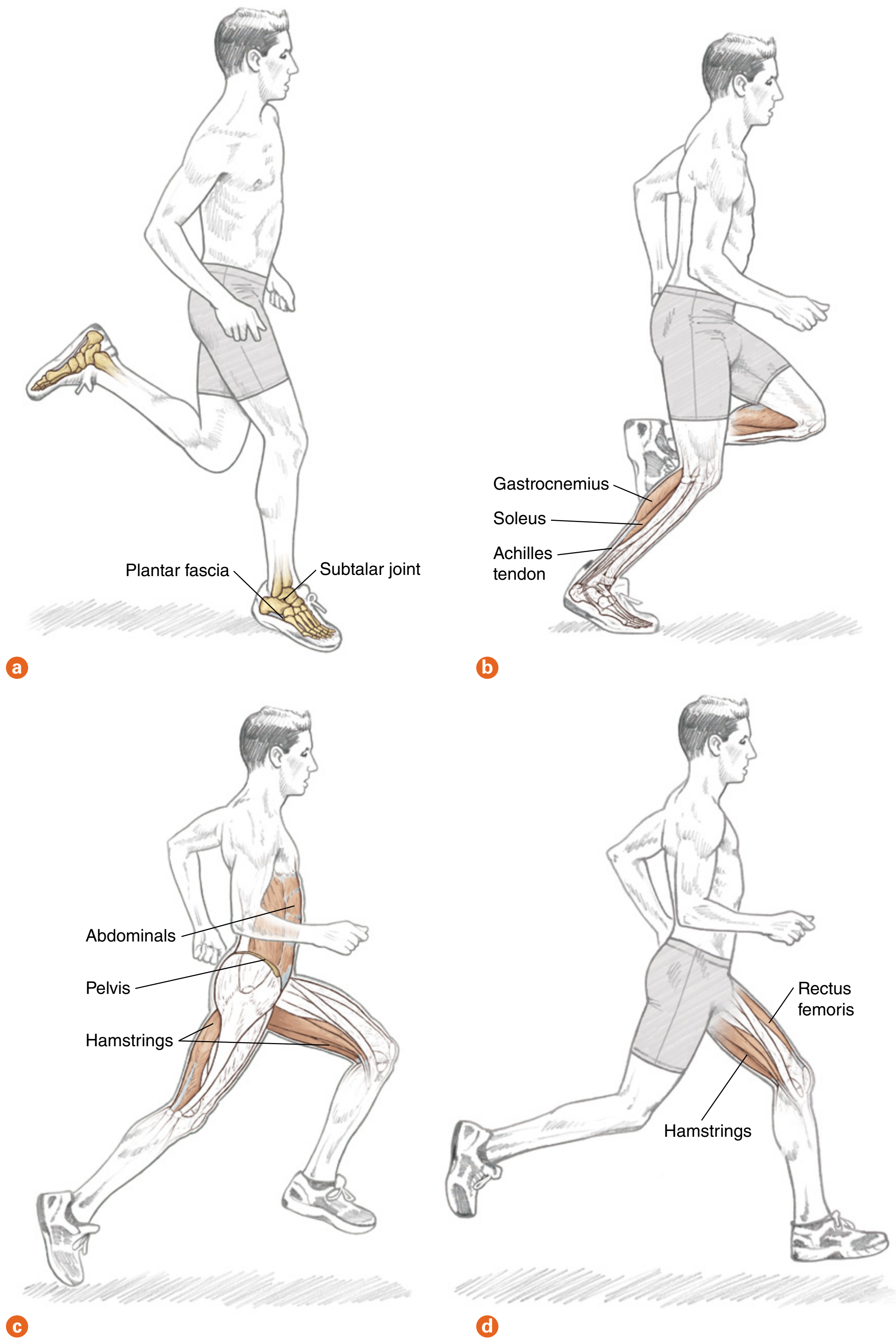

FIGURE 1.1 The gait cycle: *(a)* initial contact, *(b)* stance phase, *(c)* takeoff, and *(d)* forward swing phase.

Stance Phase

Before the foot makes initial contact (last 20% of the swing phase), the quadriceps group, primarily the rectus femoris, is very active. Once contact is made, the impact of landing is dissipated by the muscles (the tibialis anterior and gastrocnemius), tendons, bones, and joints of the foot and lower leg. More specifically, as described in chapter 4, this dissipation results from three related but separate foot movements: The subtalar joint inverts and everts, the midfoot abducts or adducts, and the forefoot dorsiflexes and plantar-flexes.

Ideally, this interaction of the lower-leg anatomy produces a small amount of *pronation,* or inward collapsing, of the rear foot. The pronation helps dissipate the shock of the landing by spreading the impact over the full surface of the foot at midstance. In contrast, an underpronated foot at midstance is less prepared to cushion the impact of landing because only the lateral aspect of the foot is in contact with the ground. This type of biomechanics normally leads to chronically tight Achilles tendons, posterior calf strains, lateral knee pain, and iliotibial band tightness (all covered in chapter 9); the same conditions may also cause opposite injuries! Conversely, an overpronated foot at midstance can result in tibia pain, anterior calf injuries, and medial-side knee pain because of the internal rotation of the tibia, or cause the same injuries previously listed for an underpronated foot! Obviously, then, neither extreme—a high, rigid arch that underpronates or supinates or a low, hypermobile arch—is ideal. Mild to moderate pronation, however, is both normal and very effective at handling impact stress.

The final part of the stance phase is referred to as *propulsion, push, or toe-off.* The more adept the athlete is at pushing the foot off the ground by engaging the gluteus and core muscles and consciously using the tibialis posterior, the less contact time the foot will have with the ground. Less contact time normally means faster turnover and, given the same stride length, faster performance.

Swing Phase

After the initial contact and midstance positioning, propulsion is enabled by various muscles working in conjunction. These muscles include the hamstrings, the hip flexors, the quadriceps, and the muscles of the calf (gastrocnemius and soleus). While this leg is finishing the stance phase and is entering the swing phase, the other leg is finishing its own swing phase and is preparing to begin a stance phase, completing a cycle of its own. Having already ended contact with the ground, this second leg begins its forward motion as a result of the forward rotation of the pelvis and the concurrent hip flexion caused by the psoas muscles. As this leg passes through the forward swing phase, the hamstrings lengthen, thus limiting the forward extension of the lower leg, which had been extended by the quadriceps. As the torso accelerates, the lower leg and foot begin to descend to the running surface, thus creating a vertical line from head to toe on impact.

Note that two cycles, one performed by each leg, are happening at the same time. As one foot takes off from the ground to begin its swing phase, the other leg prepares to begin its stance phase. This dynamic nature of the running movement makes it difficult to isolate the parts of the anatomy involved because—unlike in walking—potential energy (the energy stored in a physical system) and kinetic energy (the energy of a body resulting from its motion) come into play simultaneously. Essentially, the muscles involved in running are constantly turned on both as agonists (as prime movers) and as antagonists (engaging in opposing or stabilizing motion), creating both eccentric and concentric contractions.

The role of the core during the stance phase is identical to its role in the swing phase: providing stability for the upper body, which allows the pelvis to twist and rotate in its normal manner. Stabilizing the pelvis so that it can function appropriately is crucial because, as we have seen, the gait cycle is defined by one leg moving through the stance phase while the other leg simultaneously moves through the swing phase. A more lengthy discussion of the core is found in chapter 6; for now, suffice it to say that an unstable core can negatively affect the gait cycle and lead to injury.

Stability and balance are also aided by the arms, but in a slightly different way. Specifically, each arm counterbalances the opposite leg, so that when the right leg swings forward the left arm swings forward as well, and vice versa. In addition, the arms counterbalance each other, thus helping to keep the torso stable and in good position and ensuring that arm carriage moves forward and back rather than side to side in a swaying motion. In contrast, poor arm carriage costs the runner both by hindering running efficiency (shortening stride length as the legs "follow" the swaying arms and rock slightly) and running economy (because poor form dramatically increases energy consumption).

Given that the gait cycle involves the legs performing their cycles simultaneously—and that the same parts of the anatomy (i.e., muscles, tendons, and joints) perform multiple functions simultaneously—it is likely that breakdowns, or failures, will occur in the kinetic chain. Such a breakdown usually happens because of inherent biomechanical imbalances that are exacerbated by the dynamic repetition of the running motion. For example, the quadriceps group and the hamstrings group are both involved in the landing phase of the gait cycle. The quadriceps group extends the leg, and the hamstrings limit flexion at the knee. Because the quadriceps group is dramatically stronger, the hamstrings must be able to work at their optimal capacity in order for the movement to be fluid. If the hamstrings group is weakened or inflexible, the resulting imbalance will lead to injury.

This is just one obvious example of the injury potential of anatomical imbalances. To prevent this scenario and others, this book offers a comprehensive strength-training regimen. The exercises complement each other by developing both the agonist and the antagonist muscles, as well as strengthening the joints.

ABC RUNNING DRILLS

Aside from strength training, how can one improve running form and performance? Because running involves a neuromuscular component, running form can be improved through specific form drills that coordinate the movements of the involved parts of the anatomy. The drills, developed by coach Gerard Mach in the 1950s, are simple and cause little impact stress. Essentially, these drills, commonly referred to as the ABCs of running, isolate the phases of the gait cycle: knee lift, upper leg motion, and push-off. By isolating each phase and slowing the movement, the drills, when properly performed, develop the runner's kinesthetic sense, promote neuromuscular response, and aid in strength development. A properly performed drill should lead to proper running form because the drill becomes the running performance—just at a faster velocity. Originally, these drills were designed for sprinters, but they can be used by all runners. They should be performed once or twice per week and can be completed in 15 minutes. Focus on proper form.

A Motion

The A motion (figure 1.2*a*, *b*, and *c*) is propelled by the hip flexors and quadriceps. The movement can be performed either while walking or, more dynamically, as the A skip or A run. The movement involves knee flexion and forward rotation of the pelvis (figure 1.2*c*). Meanwhile, the arm carriage is simple and balances the action of the lower body rather than propelling it. The arm on the opposite side of the raised leg is bent 90 degrees at the elbow; it swings forward and back like a pendulum while the shoulder joint acts as a fulcrum. The other arm moves simultaneously in the opposite direction. Both hands should be held loosely at the wrist joints and should not be raised above shoulder level. Emphasize driving down the swing leg, which initiates the knee lift of the other leg.

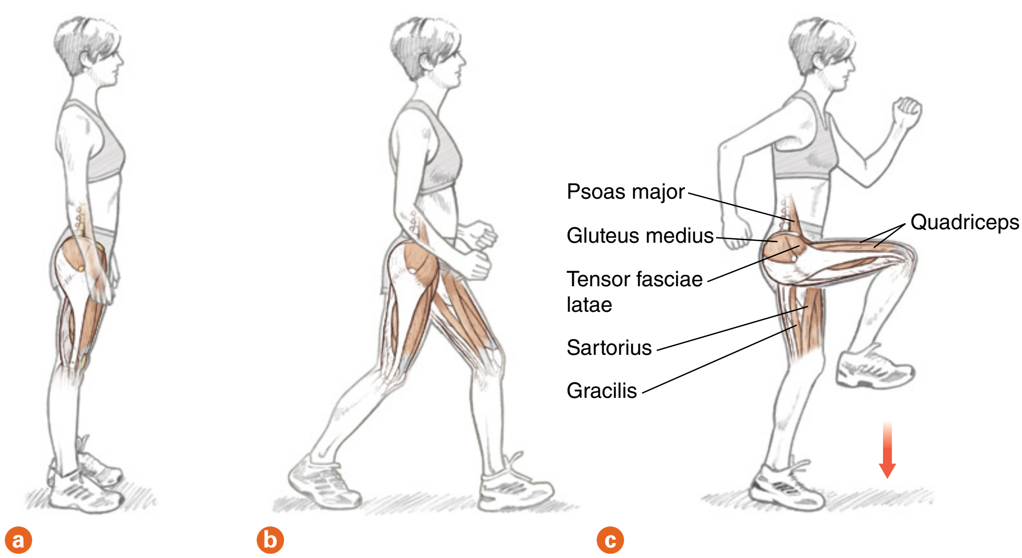

FIGURE 1.2 *(a)* A motion 1; *(b)* A motion 2; *(c)* A motion 3.

B Motion

The B motion (figure 1.3*a*, *b*, and *c*) depends on the quadriceps to extend the leg and the hamstrings to drive the leg toward the ground in preparation for the impact phase (figure 1.3*c*). In sequence, the quadriceps extend the leg from the position of the A motion to potential full extension, then the hamstrings group forcefully drives the lower leg and foot to the ground. During running, the tibialis anterior dorsiflexes the ankle, which positions the foot for the appropriate heel landing; however, dorsiflexion should be minimized in the B motion so that the foot lands closer to midstance. This precision reduces the impact experienced by the heel; in addition, because the biomechanics of the foot are less involved here than in running, this motion does not promote forefoot injury.

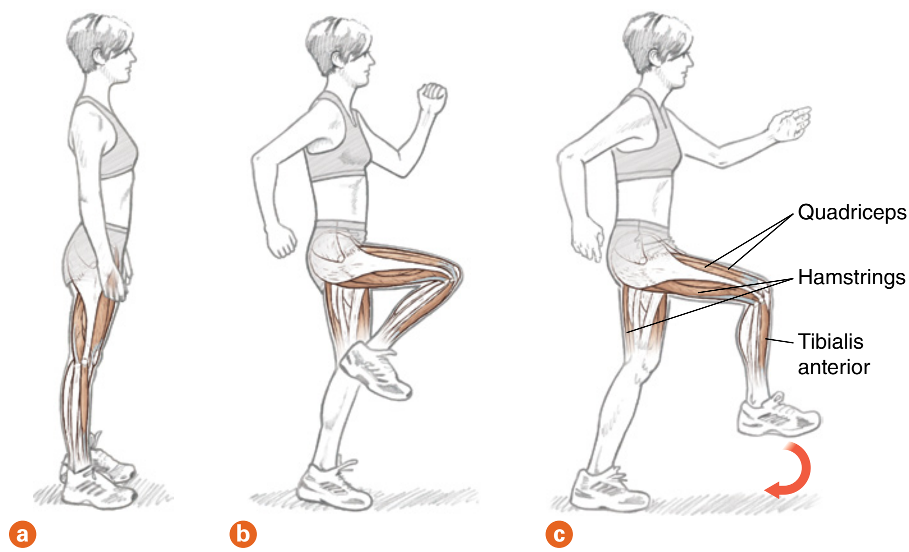

FIGURE 1.3 *(a)* B motion 1; *(b)* B motion 2; *(c)* B motion 3.

C Motion

The final phase of the running gait cycle is dominated by the hamstrings (figure 1.4*a* and *b*). When the foot makes contact with the ground, the hamstrings continue to contract, not to limit the extension of the leg but to pull the foot upward, under the glutes, in order to begin another cycle. Accordingly, the emphasis of this exercise (figure 1.4*b*) is to pull the foot up, directly under the buttocks, thus shortening the arc and the duration of the phase so that another stride can be commenced. This exercise is performed rapidly, in staccato bursts. The arms swing quickly, mimicking the faster movement of the legs, and the hands come a little higher and closer to the body than in the A and B motions. This motion is also facilitated by a more pronounced forward lean of the torso, similar to the body position used in sprinting.

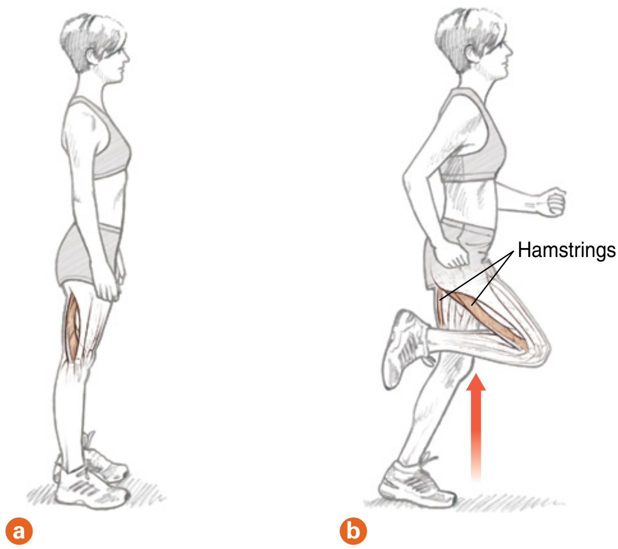

FIGURE 1.4 *(a)* C motion 1; *(b)* C motion 2.

CONCLUSION

Although runners can be directed toward a certain style by their coaches, it may be hard to maintain that style as tiredness creeps in during exercise. In such cases, a runner is liable to revert to moving in a natural way that suits his or her body build. That style may not be pretty to look at, or even the most efficient way of running, but it tends to be inevitable as fatigue sets in. In the next chapter, we look at the effect of strength training on limiting this bias, among other ways of improving a runner's anatomy.

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2

TRAINING CONCEPTS

Improvement in running performance hinges on many factors. In this chapter, we will examine how a physiological effect of training (lactate production) and an unconscious neurological effect described by the central governor model (CGM), may both play a role in performance. Also in this chapter, we will explain different types of training concepts, paying specific attention to how the each method benefits the cardiovascular and cardiorespiratory systems, which should, in turn, lead to an improvement in running performance. Since neglecting or abusing the musculoskeletal system through inappropriate training—specifically, too little strength training or too much mileage covered at too fast a pace can negate improvement we present each methodology's best practices and acknowledge its shortcomings when not properly executed. Even intelligent training, however, can exacerbate muscle imbalances and anatomical shortcomings. Incorporating strength training into a holistic plan for performance enhancement makes sense on many levels.

CARDIOVASCULAR AND CARDIORESPIRATORY SYSTEMS

The cardiovascular system is a circulatory blood delivery system involving the heart, blood, and blood vessels (veins and arteries). Put simply, the heart pumps blood. The blood is carried away from the heart by arteries that deliver it to muscles, tissues, and organs, after which it is returned to the heart by veins (figure 2.1).

The cardiorespiratory system involves the heart and lungs. Air is inhaled by breathing through the mouth and nose. The diaphragm and other muscles push the air into the lungs, where the oxygen

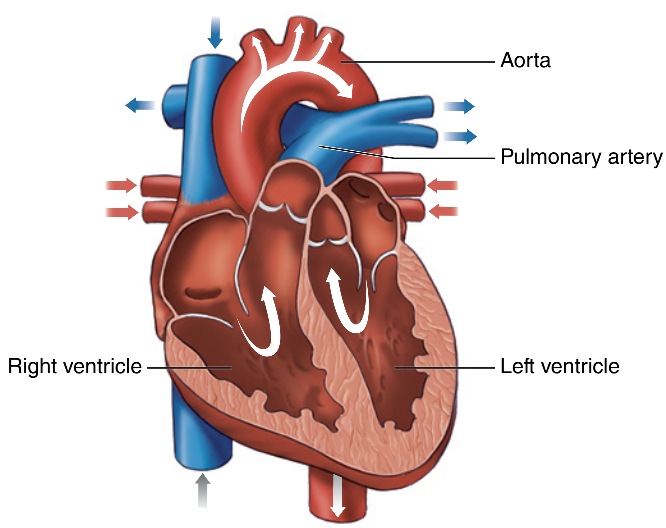


FIGURE 2.1 Blood flows through the chambers of the heart.

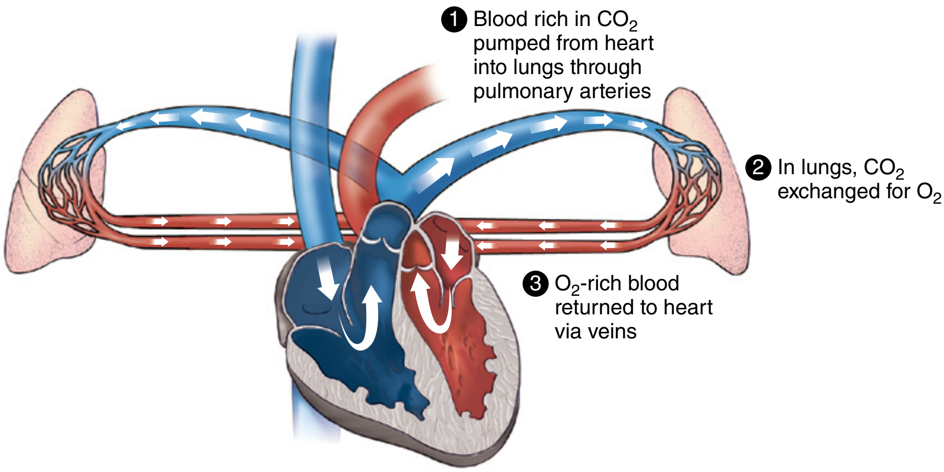


FIGURE 2.2 Oxygen exchange in the lungs.

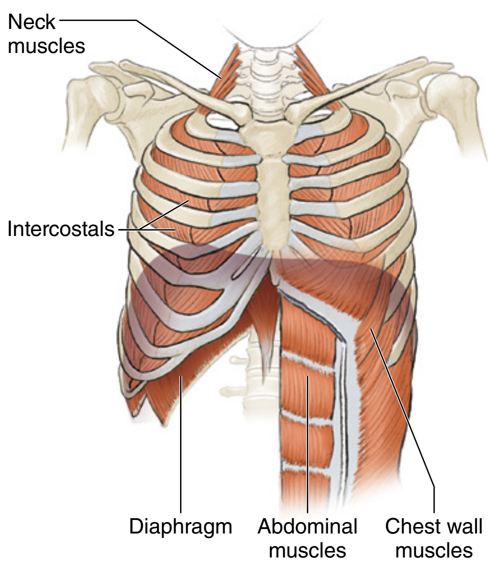


FIGURE 2.3 Muscles that aid in respiration.

contained in the air becomes mixed with blood (figure 2.2), which is then pumped through the body. Figure 2.3 shows the muscles that work during respiration.

The interplay between the two systems works when the heart pumps blood to the lungs through the pulmonary arteries. The blood is mixed with air (oxygen) that has been inhaled. The oxygenated blood is delivered back to the heart via the pulmonary veins. The heart's arteries then carry the blood, complete with oxygen-rich red blood cells, to the body's muscles (figure 2.4) to support exercise—for our example, running.

How can running performance improve as a result of this interplay between the cardiovascular and cardiorespiratory systems? Simply, the more developed your cardiovascular and cardiorespiratory systems are, the more blood volume your body has. Greater blood volume means more oxygen-rich red blood cells are available to power your muscles and more plasma is available to aid in creating energy through a process called *glycolysis.*

Other factors such as neuromuscular fitness, muscular endurance, strength, and flexibility are involved in improving running performance. Coupled with a strong foundation of well-developed cardiothoracic systems (the heart and lungs are located in the thorax region of the body, hence the term *cardiothorax*)—these other factors will help to produce sustainable improvements in performance.

The science described in the preceding paragraphs becomes exercise science, and a useful primer for improving running performance when applied to a training model. The following discussion of training is rooted in the anatomy and physiology of the cardiovascular and cardiorespiratory systems.

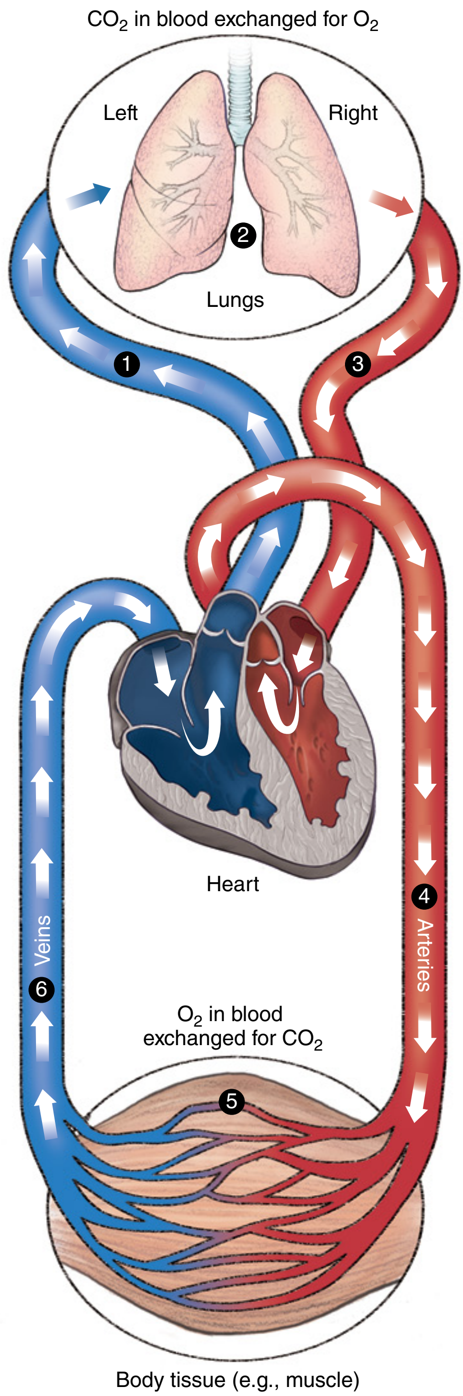


FIGURE 2.4 Circulation of blood through the heart, lungs, and muscles.

TRADITIONAL PERFORMANCE TRAINING PROGRESSION MODEL

A traditional training progression model (figure 2.5) normally consists of a well-developed base, or introductory period, consisting of easy runs of gradually increasing duration (as fitness improves) and strength training consisting of lighter weights and a high repetitions. Normally this is period or cycle is followed by a slightly shorter but still significantly lengthy duration of running strength (power) training (threshold training and specific hill work) and strength training incorporating increasing resistance. The final phase is defined by a brief period of high-intensity ($\dot{V}O_2$max) running coupled with a maintenance period of resistance training followed by a period of planned rest days (taper). This training progression is then adapted based on its success or failure and the race distances to be completed in the future. It is then repeated after incorporating a well-defined rest period at the end of each cycle for the duration of the runner's performance-based running career.

This section will explain different training concepts and their application. Often, apparent differences in training philosophy boil down to simple semantics. Since training language is not codified, coaches do not always understand and apply terminology the same way. Our goal is to present an overall concept of different training tactics and to bridge any semantic differences that may prevent a thorough understanding of the different approaches to running training.

Ultimately, the use of running training and resistance training serves one goal: to improve running

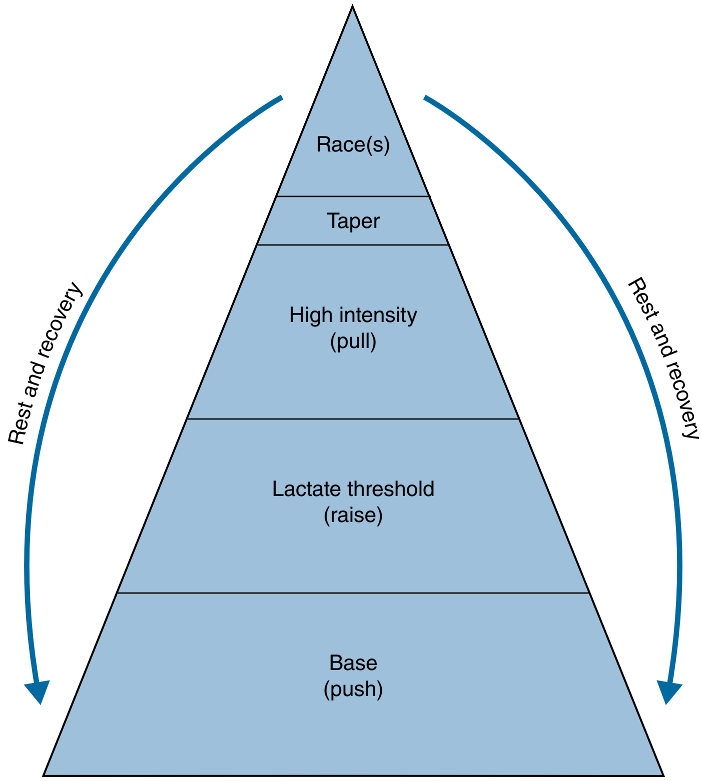


FIGURE 2.5 Phases of the training progression model.

performance. To achieve this goal, according to the traditional model, runners need to increase their lactate threshold (LT) pace, which can be generally defined as the pace at which a non-elite runner can optimally run a 8K to 10K race. The pace tends to be expressed as a range (say, 8:00 to 8:10 per mile), rather than as a specific number, which can be overly limiting due to variations in course difficulty, terrain, and weather conditions.

To increase lactate threshold pace, coaches and scientists have proposed multiple theories about how to train. Essentially, the theories attempt to either *push* the LT up via aerobic threshold work, *raise* the LT by means of work at goal LT pace, or *pull* the LT up via $\dot{V}O_2$max training, thus making the current LT pace easier and more economical.

The majority of running for each of the phases is endurance or relatively easy running. Labeling the phases provides a visual cue to understand the developmental objective of each phase.

Base, or Introductory, Training (Push)

The concept of base, or introductory, training is relatively simple, but the application is slightly more nuanced. The concept of a large base phase was a keystone of the Lydiard-style training that was prevalent during the late 1950s and the 1960s. Most coaches would agree that the pace of running during this phase is always easy (although Lydiard encouraged faster-paced efforts to increase aerobic threshold), not strenuous and anaerobic (using oxygen present), and that the volume of training should increase gradually. Down, or lesser-volume, weeks should be used to buffer the gradual trend of an increase in volume, aid in recovery, and promote adaptation to a new training load.

One systematic approach using a three-week training cycle incorporates four to six days of running training with a weekly increase in volume of 10 percent (although this percent seems to be wholly random and not scientifically verified, it is not a bad rule to follow) from week 1 to week 2; week 3 repeats the volume of the first week. For injury prevention, the weekly long run should not account for more than 25 percent of the week's total volume (see Jack Daniels, *Daniels' Running Formula*, Third Edition [Champaign, IL: Human Kinetics, 2014]), although successful coaches have used up to 33 percent, and Pete Pfitzinger and Scott Douglas (*Advanced Marathoning*, Second Edition [Champaign, IL: Human Kinetics, 2009]) recommend doing two longer runs during a single week. Two or three strength-training sessions emphasizing proper form and movement, not volume of weight, would complement this running training.

When training for a race longer than a 10K, this phase of the training cycle is the longest because of the slower adaptations to training made by the cardiothoracic systems (relative to speed and muscle) development. Since relatively slow-paced runs take longer, they require the repeated inhalation of oxygen, the repetitive pumping of the heart, and uninterrupted flow of blood from the lungs to the heart and from the heart to the muscles. All of these actions aid in capillary development and improved blood flow. Increased capillary development helps both in delivering more blood to muscles and in clearing muscles and other tissue of waste products that could impede the proper functioning of muscles. However, these adaptations take time. In fact, full cardiovascular development of a distance runner may take a decade or more, as compared with perhaps half that time for athletes who focus on faster-paced running. This longer development period explains why sprinters compete at elite levels in their early to mid-twenties, whereas distance runners rarely reach their prime until after their mid-twenties.

A training program that ignores or diminishes the importance of the base training component ignores the tenets of exercise science. Without extensive reliance on easy aerobic running, any performance-enhancement training program is destined for failure. A common question is how long the base period should last. This seemingly simple question lacks a simple answer, but the best reply is that the base period needs to last as long as the athlete needs to develop good running fitness and musculoskeletal strength based on subjective interpretation of how easy the daily runs *feel* but not so long that the athlete becomes bored or unmotivated. A good guideline for experienced runners who are training for races longer than 10k is six to eight weeks. Experienced runners training for 10k races or shorter distances need four to six weeks of base work. For beginning runners, the base period takes longer and may account for the bulk of the first four to six months of running.

A common question is how fast the athlete should run during an "easy" run. Short of getting a lactate threshold or stress test to establish specific values, a conservative recommendation is 70 to 75 percent of maximum heart rate. In another approach, Dr. Philip Maffetone offers a formula to use in figuring your ideal value for maximum aerobic-training heart rate (not to be confused with maximum heart rate!). The formula begins with the number 180, subtracts your age, and then adds or subtracts additional percentage points based on answers to specific questions about your recent training volume and health. For more information, see Maffetone's article titled "The 180 Formula: Heart-Rate Monitoring for Real Aerobic Training" (May 6, 2005, https://philmaffetone.com/180-formula). You can also use pace charts to help determine aerobic training paces based on performance in races or field tests; see *Daniels' Running Formula,* Third Edition, by Jack Daniels (Champaign, IL: Human Kinetics, 2014). These charts are extremely accurate and explain how to use the data effectively.

The best approach to strength training during base training is to perform multiple sets of 10 to 12 repetitions of exercises for total-body strength development. Specifically, at this stage of training, functional strength, although always important, is less significant than developing muscular endurance and strength for the whole body. If this is an athlete's first strength training progression, then

Lydiard Model (Push)

The late Arthur Lydiard (1917-2004) was a pioneer in aerobic running training. His concepts were so well regarded that a foundation exists to keep his coaching methodology alive and in practice. Although Lydiard training has been associated with the term LSD (long, slow distance), Mr. Lydiard's training emphasis was not long and slow, but was more aptly described as regular and with diligent effort. Moreover, it refuted the interval training methodology that had gained popularity in the 1950s due to the success of its ostensible creator, Emil Zátopek of Czechoslovakia.

Lydiard training requires practitioners to run regularly at the fastest pace they can achieve before their effort shatters their aerobic threshold, commonly held to be the measurable lactate accumulation in the blood of approximately 2 millimoles per liter (mmol/L). The ultimate goal of Lydiard-style training is to push the aerobic threshold as high as it can go before lactate accumulates close to lactate threshold levels of 3.6 to 4 mmol/L. Using running semantics, the specific goal is to increase the aerobic threshold, thus pushing up the lactic threshold, which is the point at which the body responds to excessive lactate by slowing down. Although the whole lactate model, specifically the 3.6 to 4 mmol/L ceiling, seems to be mildly arbitrary (see the discussion of the central governor model later in this chapter), it has held sway with exercise physiologists because it can be measured via blood analysis during exercise.

proper execution of the exercise is paramount. If an athlete is revisiting strength training after a rest period, then the goal is to get reacquainted with the physical demands of a combined running and strength training program. Strength training should be performed two or three times per week; however, one day a week should be entirely free of exercise, so the strength training workouts need to be performed either on running days (after runs) or on days off from running if following a four or five days/week running plan.

Lactate Threshold Training (Raise)

The term *lactate threshold* (LT) is a major conversation topic for many exercise physiologists, running coaches, and runners. We do not endeavor here to make any definitive statements about lactate threshold theories. Rather, we apply the term *lactate threshold* (please feel free to substitute *anaerobic threshold*, *lactate turn point*, or *lactate curve*) to describe the type of running that—because of the muscle contractions inherent in faster-paced training—produces a rising blood-lactate concentration that inhibits faster running or lengthier running at the same speed. Or, less scientifically, it is a comfortably hard effort that one could sustain for about 5 to 7 miles (8 to 10 km) before reaching exhaustion. It is close to 10K race pace.

Lactate—not lactic acid—is a fuel used by the muscles during prolonged exercise. Lactate released from muscle is converted in the liver to glucose, which is used as an energy source. It has been argued for years that lactic acid (chemically not the same compound as lactate, but normally used as a synonym) is the culprit when discussing performance-limiting chemical by-products caused by intense physical effort. Instead, rather than causing fatigue, lactate can help delay a possible lowering of blood glucose concentration and thus ultimately aid performance.

Threshold training also aids running performance because it provides a greater stimulus to the cardiothoracic systems than do basic aerobic or recovery runs. (Of course, without a base derived from easy running, lactate threshold workouts can't even be successfully attempted, due to the lack of aerobic fitness and the potential for injury.) Moreover, thanks to the shorter duration of lactate threshold training, it can provide this greater stimulus without producing a correspondingly high impact on the musculoskeletal system. As a result, by running at a comfortably hard effort for 15 to 35 minutes (depending on your goal race date) and timing of the effort (how close to the race date the training is done in your training program), you can accelerate the rate at which your cardiothoracic systems develop. *Tempo runs* which are often used interchangeably with *lactate threshold runs*, *cruise intervals*, mile repeats, and *steady-state runs* (which are minimally slower than tempos) are types of threshold workouts, just at slightly different paces and durations. Ultimately, these runs would all achieve the objective of a lactate-type run—that is, a measurement of 4 mmol/L of lactate if blood were taken during the run—whereas an easy aerobic run would produce almost no lactate.

A good resource on tempo-type training is *Daniels' Running Formula,* Third Edition (Champaign, IL: Human Kinetics, 2014), in which Jack Daniels indicates recommended paces and durations of effort based on fitness level and race distances to be attempted. Although less stressful on the runner's body than $\dot{V}O_2$max efforts, threshold runs in any form (tempo runs, cruise intervals, repeat miles) require longer periods of recovery than do daily aerobic or recovery runs. Most non-elite runners should perform threshold-type runs no more than once every other week during the lactate threshold phase, and these runs should be treated as hard efforts. Accordingly, they should be preceded by an easy run and a set of strides—faster running for 40 to 60 meters on the day before and followed by an easy run or off day on the day after.

Note that easy running still makes up the majority of this phase of training. The introduction of threshold-type training to the progression (and specific hill workouts) are usually the only difference from the introductory phase.

Strength training in this phase of a training progression is highly individual. The emphasis should be placed on performing functional exercises countering the athlete's weaknesses and that correlate directly with running faster. For example, if a runner lacks arm strength, then emphasis should be placed on performing arm exercises with a relatively low number of repetitions (four to six) and relatively high weight (to exhaustion). If the runner is training for a 5K, then it is also important to develop functional hamstring strength. Two powerful exercises for doing so are the dumbbell Romanian deadlift and the good-morning, which involve both the hamstrings and the glute complex, thus addressing a good bit of the portion of the anatomy involved in the running gait. Because of the intensity of the training, the muscle fibers must have a period of rest in order to repair themselves so that they can adapt to an increasing workload. Therefore, two strength training workouts per week will suffice.

Interval and $\dot{V}O_2$max Training (Pull)

Interval training is the generic term for running a relatively short distance fast with a fixed rest interval. Multiple repetitions (and sometimes sets of reps) are completed. Czech distance runner Emil Zátopek popularized this training methodology in the late 1940s and 1950s when he completed an epic 80 repetitions of 400 meters in military boots in a forest on his way to winning three gold medals at the 1952 Olympics in Helsinki. The failure of Zátopek's system was that it relied solely on the training volume of the workouts, which were conducted irregularly during the week. The regimen included little easy running to allow proper recovery or further aerobic development.

Interval training morphed into $\dot{V}O_2$max-specific workouts, which constitute a powerful training tool for improving running performance *after* performing the training leading up to it. The goal of this type of training is to pull the lactate threshold up to a higher level by running faster than lactate threshold pace.

$\dot{V}O_2$max is the peak rate of oxygen consumption during maximal or exhaustive exercise (see figure 2.6). Various tests involving exercising to exhaustion

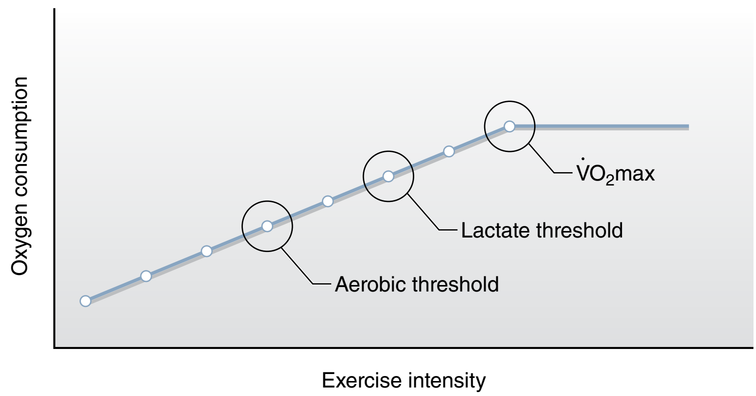


FIGURE 2.6 Oxygen consumption relative to exercise intensity.

can be done to determine a $\dot{V}O_2$max value (both a raw number and an adjusted one). Once a $\dot{V}O2$ value is obtained, a runner can develop a training program that incorporates training at heart-rate levels that equate to $\dot{V}O_2$max levels. The training efforts, or repetitions, would not necessarily end in exhaustion (although they can), but they do reach the heart-rate equivalent of the $\dot{V}O_2$max effort for a short period—about three to five minutes.

The goal of this type of training is multifold. $\dot{V}O2$ training requires the muscles involved to contract at such a fast pace as to be fully engaged, thus enhancing the neuromuscular component by placing a premium on nervous system coordination of those muscles. More important, it requires the cardiovascular and cardiorespiratory systems to work at peak efficiency in order to deliver oxygen-rich blood to the muscles and remove the waste products of the glycolytic (energy-producing) process.

Training at $\dot{V}O2$ max levels is obviously a powerful training tool because of its intense recruitment of many of the body's systems. In order for a runner to fully benefit from a $\dot{V}O_2$max training phase, it must be incorporated into the training cycle at the appropriate time. Some athletes have reported success in reversing the training progression and performing $\dot{V}O_2$max workouts at the beginning of a training cycle, but the best time to add this type of training to a performance-based plan is after a lengthy base period of easy aerobic or recovery training *and* a period of threshold training geared to a specific event. In addition, rest is an important component of this phase because it aids in adaptation to the intense stimulus of the $\dot{V}O_2$max workouts. Do not be fooled into thinking that performing intense workouts and multiple races without rest constitutes an intelligent training plan. It may deliver short-term success, but ultimately it will lead to injury or excessive fatigue.

Strength training performed at this stage should consist of a set of exercises that are highly functional and specific to the event and to the physical strength of the runner. For example, a marathon runner who has a strong core would focus on the core with multiple sets of 12 repetitions. In order to ensure balance, the exercises would be divided equally between abdominal exercises and lower-back exercises as well as the whole torso area. The emphasis is on muscular endurance. In contrast, a 5K runner whose focus is speed would continue with the lower-repetition, higher-weight routine of the threshold phase while emphasizing the upper legs, core, and upper torso.

Many exercise physiologists consider $\dot{V}O_2$max and $\dot{V}O_2$max-specific training (often referred to as interval-style training) to be the most important components of a comprehensive running program. This view has been challenged by coaches who have seen or experienced success in emphasizing lactate threshold workouts. Regardless of one's view on that particular debate, $\dot{V}O_2$max-specific workouts provide a powerful training tool for improving running performance after performing the training leading up to it.

Taper and Racing Phases

After the base, lactate threshold, and high-intensity training phases have been completed, a period of relative rest—the taper phase—should precede any racing. This caveat doesn't mean that no races are completed during the earlier phases of training. Often, in fact, completing a B-level race during an early phase of training provides a data point (or points) to aid evaluation of how the training progression is going. Without resting (tapering) for the B race, it is difficult to know exactly how the body would respond to the increased effort required for the ultimate A race (or races). Still, occasional B races can substitute for workouts and help ward off the boredom caused by monotonous solitary training.

While a runner is tapering, intensity doesn't go away—it merely diminishes in volume and frequency. For example, instead of doing a workout totaling 5,000 meters during the week, the workout would be pared down to 3,000 meters. Similarly, instead of one lactate threshold run and one interval run per week, the emphasis would be on one race-specific effort. This approach results in less stimulus and more recovery in preparation for the big race (or races). The duration of the taper is normally two to three weeks for a marathon and accordingly less for shorter distances.

Results of the Training Progression Model

Each training phase builds on the by-products of the completion of the preceding phase. They are not isolated blocks but an integrated system. For example, a completed base, or introductory, phase leads to increased capillary development, which results in greater blood volume, musculoskeletal enhancement, and, theoretically, a more efficient gait. Threshold training then furthers the runner's performance by advancing the development of the cardiothoracic systems, increasing the adaptation of the musculoskeletal system through faster muscle contractions, and heightening the body's neurological response to stimulus (through faster-paced running). Then, $\dot{V}O_2$max training helps pull the lactate threshold up, thus allowing the previous LT pace per mile to become an aerobic pace. Anaerobic training (using oxygen already present) has little practical application to distance running and does not factor into the training progression for most non-elite runners.

The specifics of pace, duration, and rest can be found in many training manuals, and the specific application of each type of training varies with the individual. By following the strength training recommendations for each phase of the running training progression, a runner is really preparing the body for the rigors of a goal race or races.

The result of a training program based on developing the cardiothoracic systems results is better performance through an improved "engine" (the heart and lungs) and a stronger "chassis" through strength training. Whether $\dot{V}O_2max$ is determined by exhaustion of the heart first or the muscles first, the development of the cardiothoracic systems permits the point of exhaustion (measured in terms of heart rate) to be reached at a faster pace and allows a greater distance to be covered. This is a visible way in which performance improvement can be measured. However, to extend the vehicle metaphor, the "brain" of the car has recently also been given its due in terms of running performance—specifically, the point at which the body begins to fail.

CENTRAL GOVERNOR MODEL

"It's all in your head." As a serious-minded runner, how many times have you heard that phrase from a coach or training partner when you were incapable of completing (or even beginning) a fast or long workout or race? The sentiment is meant to imply that your desire to slow down or even stop isn't a physical sensation per se but a psychological (actually, neurological) sensation. Such phrases have often been uttered to indicate performance anxiety or lack of competitiveness.

In the late 1990s, Dr. Timothy Noakes of South Africa hypothesized that fatigue felt during running exertion does indeed reside in your head, but not in the way just described. Rather, he posited that a certain set of physiological conditions can cause unconscious messages to be transmitted neurologically from the brain to the muscles (A. St. Clair Gibson and T.D. Noakes, "Evidence for Complex System Integration and Dynamic Neural Regulation of Skeletal Muscle Recruitment During Exercise in Humans," *British Journal of Sports Medicine*, 38[6]: [2004] 797-806). In this theory, your mind governs your physical movement—specifically, the intensity of your exertion—and thus protects your body from debilitating damage. In other words, your unconscious mind maintains homeostasis, thereby preventing you from destroying your physical self, by controlling how much work or training you can accomplish. In this view, then, the runner's ultimate limiter is not lactic acid but the mind, which acts as the "central governor" of exertion. This is the central governor model (CGM).

Fatigue from exertion has commonly been described in two ways: Brain and spinal cord activities are considered to reflect, ultimately, central fatigue within the mind. In contrast, supreme effort involving the muscles is considered the domain of peripheral fatigue affecting the body.

It seems impossible to thoroughly separate the body from the mind, but the widely accepted lactic acid paradigm purports to do just that. It presupposes that the physiological response to intense running slows you down. Mind and body are also separated in CGM theory but to a lesser extent. Again, the CGM postulates that a runner's ability to endure fatigue is limited by preconceived notions of exertion (both conscious and unconscious) in order to preserve homeostasis. Therefore, if the unconscious mind could be reprogrammed (the conscious mind's self-control wanes over time), then previous limitations on effort—and thus on performance—could be shattered, enabling runners to go faster and longer.

The real answer to the performance limiter question can probably be found in the interplay between the traditional lactate accumulation model and the CGM. The CGM came about, in part, to explain why there were so many outliers to the commonly held position that at a particular level of exertion the concentration of lactate in the blood would begin to limit performance. At the same time, one shortcoming of the CGM theory as the sole determinant of performance limits is the argument that a neurologically rewired central governor would put no limit on how fast and far an athlete could run except for whatever the mind (the runner's neurological and psychological components) could convince the body (the runner's physiological components) to attempt. It stands to reason that some physiological determinant (such as lactate threshold) must play a role. For a more thorough discussion of the CGM and theories on the role of the brain in performance, please see Alex Hutchinson's *Endure: Mind, Body, and the Curiously Elastic Limits of Human Performance* (New York: William Morrow, 2018).

Ultimately, the most important questions may be the following: Can we establish a valid ratio range for blending the two theories, and, if so, how can we apply it to individual runners with different muscle-fiber concentrations and other physiological and psychological strengths and weaknesses? The answers to these questions are intertwined. We can indeed establish a valid ratio (though it may fluctuate over time), but it is predicated on the individual; in other words, no single, perfect ratio exists. Just as muscle-fiber ratios vary from runner to runner, so does psychological makeup. Therefore, the key to establishing a ratio for blending these two theories lies in understanding (on the part of the athlete or the coach) the athlete's individual physiological and psychological makeup.

STRENGTH TRAINING GUIDELINES

Following a strength training plan while running doesn't guarantee faster times, but it does guarantee the development of a better muscular foundation that allows the runner's body to achieve and maintain proper form for itself while training. Maintaining proper form eliminates or at least minimizes the risk of injury (if the training plan is sound), thus allowing for consistent training that leads to improvement. This improvement may include faster times; it will definitely include subjectively better running performance.

Chapters 4 through 8 provide detailed examination of the parts of the anatomy affected by running. We begin with the feet and ankles (chapter 4), then move up in succession to the legs (chapter 5), the core (chapter 6), the shoulders and arms (chapter 7), and the chest and back (chapter 8). Each chapter begins by explaining how the relevant parts of the anatomy are engaged while running, then presents specific exercises and describes their purpose and proper execution.

Chapter 9 addresses common running injuries and presents some exercises to prevent them and recover from them—a little prehab and a little rehab. Strength training can include a variety of approaches, including physical therapy exercises that don't require weights, weighted resistance exercises using machines, and exercises that use free weights. We've tried to strike a balance in these exercises between functionality and ease of performance. Of course, hundreds of outstanding exercises exist for each muscle group, so there may be a few favorites that we've not included here. Please feel free to add them for the sake of variety and of achieving a well-rounded strength training program.

Resistance

Initially, take care to choose weights for each exercise that provide moderate resistance while allowing the use of proper technique for the entire set of repetitions. Increase the weight as strength improves and adaptation becomes apparent through easier performance of the exercise. Never use a weight so heavy that it compromises proper technique, even on the final few repetitions of a set.

Decisions about how much weight to use should also consider which part of the anatomy is being strengthened. For example, the pectoral muscle is large and therefore can handle a large amount of work. In contrast, the triceps brachii, which consists of three much smaller muscles, fatigues quite quickly when used as the primary mover. In addition, because the triceps brachii is involved secondarily in many upper-body exercises, it will already be slightly fatigued before any triceps-specific exercises are performed. Therefore, it can be strengthened sufficiently by performing one triceps-specific exercise per strength training session involving the arms. Conversely, multiple chest exercises, or many sets of the same exercise, will be needed to sufficiently fatigue the larger pectoral muscle.

Repetitions

The number of repetitions should vary based on the strength training goal of the exercise and the objectives of the entire strength training workout for that day. For example, two sets of 20 dumbbell presses and a set of 30 push-ups might serve as an entire chest workout on a Monday, whereas Friday might feature one set of 12 repetitions with a heavier weight followed by two sets of 10 repetitions of incline barbell presses and three sets of 15 push-ups. As a rule, perform fewer repetitions with heavier weights and more repetitions with lighter weights.

Breathing

When forcibly moving the weight, exhale; when performing the negative movement, or resisting the weight, inhale. In short, exhale when generating movement, and inhale when resisting movement. Each exercise should be performed as fluidly as possible in a controlled manner and should be synced with the breathing pattern. An accepted breathing pattern is four seconds for the resistance (inhalation phase) and two seconds for the movement (exhalation phase).

Schedule

A varied resistance-training routine works best, but there is a caveat regarding the concept of "work plus rest equals adaptation." The work must change over time, both in quantity (amount of resistance) and in quality (type of exercise) in order to ensure continued strength gains.

For each segment of the body examined in this book, we provide multiple exercises (some with variations) that can be used to create a multitude of strength training sessions. All exercises are geared toward strengthening the parts of the anatomy that are most involved in running. Runners can tailor their strength training sessions to meet their fitness needs and time constraints by changing the exercises selected, the number of sets and repetitions, and the order of exercise performance. No workout need be longer than 30 minutes, and two or three sessions per week can dramatically enhance a runner's performance by strengthening the specific parts of the anatomy used during running training and racing.

We are not suggesting that merely lifting weights will make you a better runner. We *are* suggesting that the strength you gain from proper strength training will aid your running performance. Specifically, it will aid in respiration and eliminate muscle imbalances that can impede the gait cycle and contribute to injury.

CONCLUSION

In this chapter, we've explained the concept of running training progression and its limiters. We've also begun a discussion of strength training for runners, which we will continue in chapters 4 through 8 by isolating parts of the body and suggesting functional exercises to strengthen them. First, however, chapter 3 addresses some of the external factors that affect performance.

3

EXTERNAL FACTORS THAT AFFECT PERFORMANCE

Every runner has a vision of the perfect run. Perhaps yours goes something like this: beautiful views; a gentle, cooling breeze; a benign, perhaps slightly downhill surface; and a supportive companion. Sadly, the real world is rarely like that, and we all have to make do with some sort of compromise on these fronts. The weather may be wet, windy, and cold; the surface rutted and uneven; the view industrial; and the companion a rival. In such circumstances one's body and mind must adapt to the prevailing conditions—either that or give up! This chapter addresses how we can adapt in order to cope with the circumstances our sport throws at us. Although the key points presented here are illustrated by athletes from the extreme ends of the running spectrum, most runners will find a compromise somewhere between the various limits discussed.

HEAT AND HUMIDITY

Nothing is worse for a marathoner than to wake up on the morning of the big race—the focus of three or four months of preparation—only to be met with weather conditions that prevent him or her from achieving his or her goal. For instance, any combination of temperature (degrees Fahrenheit or Celsius) and dew point (water saturation of the air) that exceeds 100 requires a pace adjustment—slower! Thus even a day with a temperature of 56 degrees Fahrenheit (13 C) and a dew point of 46 (8 C), seemingly perfect for marathon running, requires a slight slowing in order to "normalize" the pace. One way in which heat affects running performance is by causing a loss of electrolytes due to perspiration. The cooling mechanism of sweating also siphons blood from the muscles and heart, which leads the heart to beat faster. Because the faster heart rate mimics the result of more exertion, the body cannot sustain the pace asked of it, and it responds by slowing down.

If you think you can beat the weather, you are wrong! You may get by for a large percentage of the workout or race, but eventually you will pay the price. It does matter slightly if you are heat acclimatized because of where you train. However, unless your training is highly specialized to maximize performance in heat and humidity, then the very act of training regularly in warm, humid weather compromises your preparation if you don't follow the pace adjustments. Heat acclimatization over a long period of time—a generation or two—should, in theory, create evolutionary acclimatization, but shorter periods of adaptation merely create better tolerance. One hypothesis regarding tolerance posits that the central nervous system—acting as the "central governor" (see chapter 2)—simply *feels* more comfortable with the hot, humid conditions and adjusts its concept of homeostasis accordingly. In other words, the runner may experience little tangible adaptation in such a short time.

Thus it seems almost futile to try to prepare for racing in high heat and humidity. And perhaps it is . . . or perhaps not. Here is some anecdotal information.

For the 1984 Olympic marathon, Alberto Salazar endured heat acclimatization training preceding the race. He ran in the late afternoon (hottest time of the day, and the start time of the race) and had a world-renowned exercise physiologist and others create a "climactic chamber" to mimic the expected conditions of Los Angeles in the late afternoon. Despite his acclimatization, he still struggled with dehydration caused by excessive sweating. He finished 14th despite having run a recent marathon in a time that was only 35 seconds slower than the world record. Conversely, the woman's marathon winner, Joan Benoit, was from Maine and didn't use "science" to adapt to the heat and humidity predicted for Los Angeles. Although she did tend to train in the heat of the day, her training was less specific than Salazar's.

A counterpoint to the Salazar meltdown comes from a story about the 1960 Olympic Games. British race walker Don Thompson, a competitor in the 50K race, prepared for the sapping heat and humidity of July in Rome by using kettles of boiling water to steam himself in a heavy tracksuit in the modest bathroom of his home. At the Olympics, he won an unexpected gold medal. This is an extreme example that we would strongly discourage you from following! However, practicing in conditions that resemble those of competition is unlikely to do any serious harm, and some researchers argue for it, especially if adequate time is left for recovery and if lessons are learned from the experience. It may not be entirely possible for runners to simulate race conditions, and the domination of long-distance races by Africans in the 21st century may be partly a result of evolution, but their performance is influenced by living at altitude and by a lifestyle that may require children to run 5 or 10 miles to and from school in order to be educated. If kids in Western civilizations had to do the same, might they have similar successes in running?

Although these examples do not prove or refute a hypothesis, they do provide context for considering the fact that most current efforts to address heat and humidity focus on doing so in the moment rather than on achieving acclimatization. For instance, Nike created cooling vests to be worn before competition by its sponsored athletes at the 2008 Beijing Olympics. Also, at the 2008 Olympics in Beijing, some of the Australian teams drank slushies (crushed ice sweetened with flavor) to help lower their core temperature in anticipation of their activity in the heat. For the 2015 World Championships, also in Beijing, Nike created a cooling hood for decathlon world-record holder and sponsored athlete Ashton Eaton.

Ultimately, there is no disputing that heat and dew point affect performance, whether one is racing or training. Acknowledging that fact and making pace adjustments may not mitigate the discomfort of running in such conditions, but pace changes do allow you to normalize your effort and get the most out of the race. The best way to normalize performance in a race that is compromised due to high temperature, dew point, or both is to compare your overall pacing with the finish times from previous years, especially if the race has established historical data over a decade on the same course at the same time of year. For example, a marathon finish time of 4:40:00 (rounded up to 10:41 per mile) could be adjusted by 2 percent to account for a temperature and heat index sum of more than 130, at 65 degrees Fahrenheit (18 C) and 65 dew point (18 C). The adjustment would yield a finish time of 4:45:42 (rounded up to 10:54 per mile), which, although 5 minutes slower than goal pace, should compare well with the rank that a 4:40:00 marathoner historically achieves in normal conditions. The same percentages apply to training; whether for a workout or an easy run, pace will be adversely affected (see www.coolrunning.com/engine/4/4_1/96.shtml for a calculator you can use to get your own pace to figure out your own adjusted time).

One great tool for calculating pace corrections is an app named Hot Weather Pace Calculator for Runners. The app gives you the current temperature and dew point, allows you to input the goal pace and distance planned, and provides you with an appropriately adjusted pace—quite a tool for runners who seek a data-driven edge! The difficulty then moves to running at that proscribed pace.

COLD CONDITIONS

It is no coincidence that the fastest sprinters in the world make the majority of their appearances—and all of their fastest runs—in the summer months. Once the temperature drops below the mid-60s in degrees Fahrenheit (the high teens in degrees Celsius), flexibility is lost in the ligaments and joints of the lower limbs and blood flow decreases through the muscles. These effects constitute a recipe for injury, especially because winter preparation probably involves a large percentage of indoor training in warm clothing to simulate summer temperatures.

Sprinters require muscle bulk in order to deliver the explosive power needed in their events. This bulk can be obtained only by repetitive training in muscle-friendly ambient temperatures with increasingly heavy weights and drills, which eventually produce the muscle definition that is so admired and effective in their events. Watching a slow-motion image of sprinters shows how they run with every muscle available. Observe not only the legs but also the shoulders, arms, neck, and even lips of a sprinter running flat out. The winner is the one who has trained key elements individually and intensively. Usain Bolt did not just happen!

Distance runners training during cold months may opt for the treadmill to complete indoor workouts. When completing indoor workouts on a treadmill, it is beneficial to place a working fan in front (or slightly to the side) of yourself in order to cool you off by evaporating perspiration. Due to the sweating, you also need to drink more fluid than you would during a cold run.

When training outside, some runners complain of the cold air “burning” their throat and lungs; this sensation is usually a function of mouth breathing. When an athlete breathes through the nose, the air is warmed and humidified in the nasal cavity and sinuses, which essentially act as a respiratory heat exchanger, before even reaching the lungs. Persons with asthma are more prone than others to adverse responses to cold air, but there does not appear to be a specific low temperature or level of humidity that triggers an adverse response.

Wearing layers is essential during winter training. Compression clothing is preferred over looser clothing because it helps elevate skin temperature. Though compression clothing does not elevate core temperature (layering helps with that), it does produce an elevated skin temperature that enables muscles to warm up more thoroughly and quickly, thus helping to prevent injury.

TERRAIN

Sprinters have little to worry about underfoot. For the past 40 years, the majority of tracks have been built with a rubbery surface, which provides elastic rebound after landing. These tracks contributed to injury when first introduced because of the shock of the bounce-back and the Doppler effect on the untrained muscles and Achilles tendons. However, as such tracks have become more numerous, training on them has helped reduce the incidence of injury.

The situation is rather different for longer-distance runners once they leave the track. Roads themselves vary from hard concrete to soft tarmac, and even standing water changes the forces produced on landing. All of these factors alter the shock waves and the body’s responses, particularly in the lower limbs.

An even more difficult adaptation is faced by hill and mountain runners, who not only ascend and descend straight-on (figure 3.1) but also may run slopes diagonally. These types of running exert excessive forces not only on the lower limbs (figure 3.2)—as the ankle joints need to prepare for constant inversion and eversion—but also on the knees, hips, and pelvis. These demands can result in a scoliotic, or twisted, lower back, which soon becomes painful unless appropriate steps are taken to prepare for this type of running.

Hills provide the ultimate test of one’s ability to stay upright while running. If the runner is unstable, then he or she will soon topple. Of course, those blessed with a low center of gravity have an advantage here, although their shorter legs may not deliver a long stride. Another possible advantage—in this case, one that is somewhat under the runner’s control—is a thin torso, which may lower the center of gravity; in addition, reducing one’s overall weight makes it easier

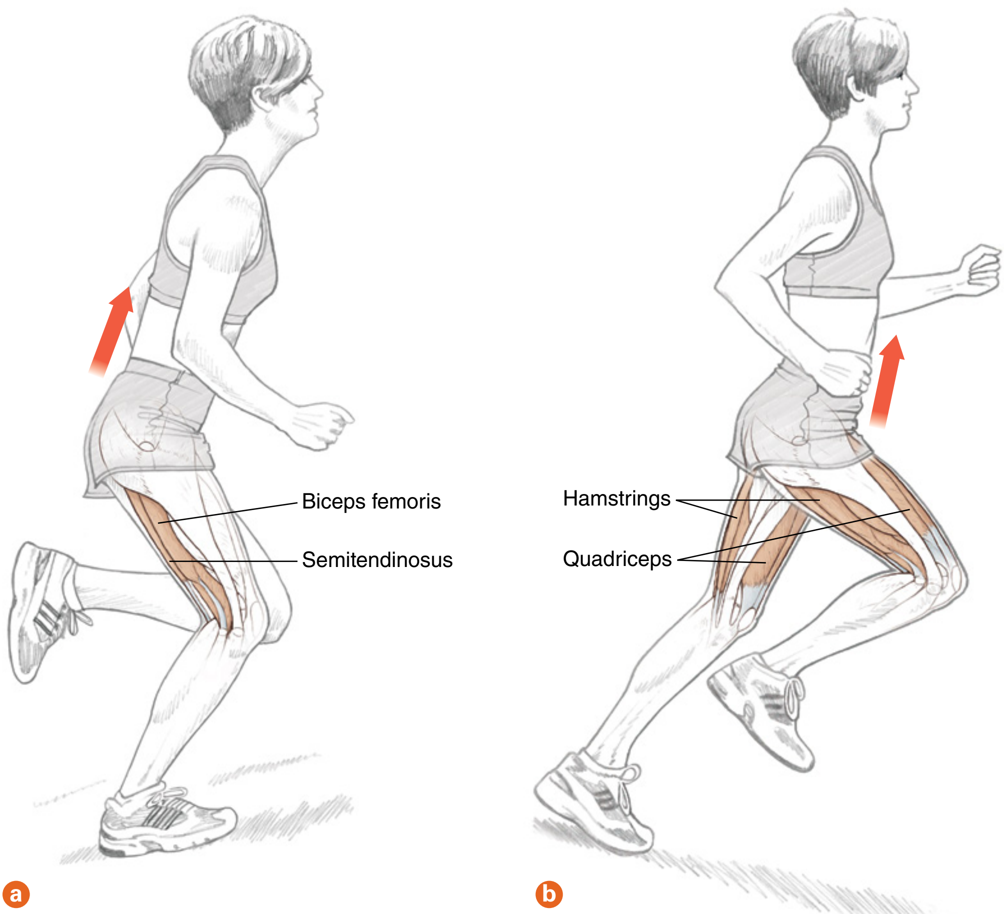


FIGURE 3.1 Running *(a)* up an incline or *(b)* down a decline requires physical adaptations.

to lift the body. Another key factor is flexibility of the spine, particularly the lumbar area, because an ascending runner needs to incline into the slope and a descending runner needs to lean backward to prevent the center of gravity from being moved forward horizontally by the running action. Because the need to lean decreases range of motion in the spine, the hips must also be flexible in order to compensate.

Although the muscles used when running a hill are the same as when running on flat terrain, the emphasis changes. Specifically, the erector spinae and iliopsoas have to work harder during a climb because a tilted spine requires more effort to hold stable than does a vertical one (in which case the vertebrae generally just sit one on top of another). Descent, on the other hand, puts more stress on the anterior muscles of the calves and thighs, which must absorb the impact of landing as well as the effect of gravity.

Because running on flat terrain cannot adequately prepare a runner for hills, some training should involve climbing, even if it uses only stairs. Downhill training is more difficult for a runner who lives on flat terrain. As a last resort,

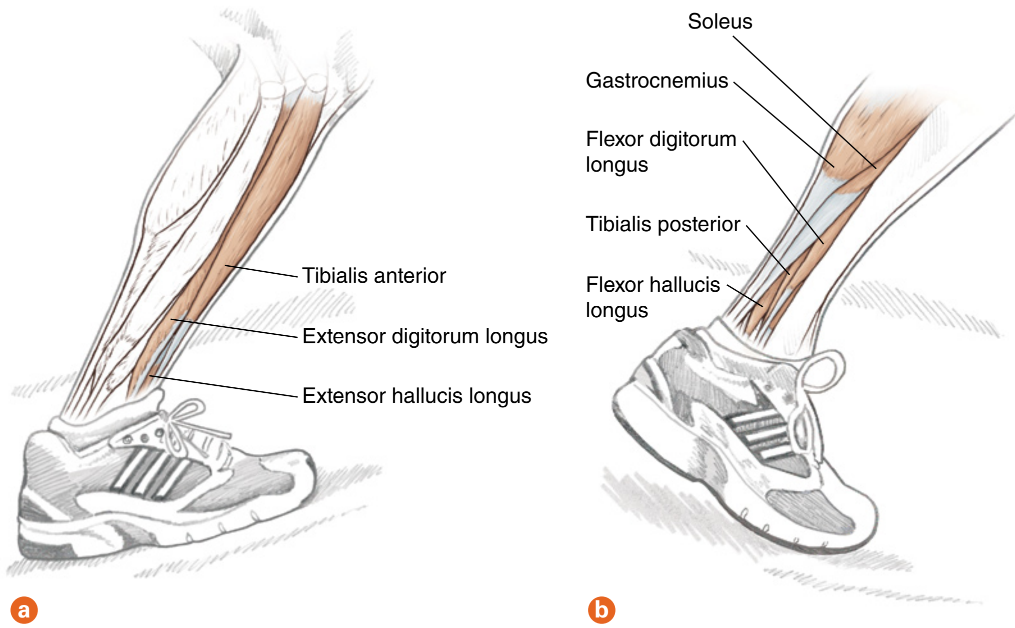


FIGURE 3.2 The lower legs and feet must adapt to *(a)* inclines and *(b)* declines.

stepping up and down can provide some relevant training and some experience of the problems involved in running hills, especially if the action is maintained for several minutes. Hill training can be used as part of the base phase, the lactate threshold phase, or the high-intensity phase of training (chapter 2), depending on the workout's construction. As for specific muscles involved, the climbing muscles in the calves (chapter 4) and the glutes and anterior thighs (chapter 5) can be strengthened using the exercises listed in the relevant chapters. Runners who live in flat areas with little change in elevation suffer from chronic overuse injuries to the anterior muscles of their core (chapter 6), whereas their posterior muscles often atrophy because of lack of use.

Cross country running is sufficiently global to boast its own world championships, though all too often the races are run on grassy surfaces. Real aficionados prefer a course covering 6 miles (10 km) or more of deep, glue-like mud that requires them to lift their legs out with each stride while trying not to slip backward on the treacherous ground. Although one's choice of footwear may aid in such movement, it does little to prepare one for the increasingly exhausting effort demanded by each stride as compared with the rebound experienced when running on a road.

Bends and corners present their own difficulties. Runners must lean into a corner at a right angle in order to avoid falling flat on their sides. Indoor tracks, which are half the length of outdoor tracks, are steeply banked to allow runners to lean less obviously and thus concentrate more on staying in their own lanes as they double back through 180 degrees. Bend running stresses the lateral outer side of the lower limbs; specifically, extra force is experienced by the tensor fasciae latae, the peroneal muscles, and the lateral ligaments of both the outer knee and the ankle. The medial side of the inner leg is similarly affected. Lateral forces must also be absorbed by the shoes, and laterally rippled shoes that grip mud when running forward will provide no help when the foot slides outward on a sharp corner. For these reasons, running indoors on the boards for the first time has served as a rude awakening for many experienced runners who thought they knew it all!

Because many roads have a camber, running persistently along one side of the road can leave a runner with a leg-length difference; in such cases, the leg nearer the middle of the road is shorter than the other. To compensate, the pelvis inevitably tilts, and in turn the lumbar spine twists to become vertical. If you want a recipe for low-back pain, this is it! Of course, we cannot recommend running down the middle of the road, but running on alternate sides of cambered roads may help reduce the problem.

All training must rely on the facilities available. Thus city-dwelling mountain runners are unlikely to have suitable slopes for training in their immediate area. They can still prepare to run at certain speeds and may even use the stairs in a high-rise to simulate some of the climbing action. It is more difficult to practice for a rugged, slippery, or stony surface, where one major objective is to avoid injury. At this point, one must think both about preparation and about the desired outcome. If a run is likely to involve a diagonal downhill section, then runners will perform best if they have added flexibility and strength to withstand the forces experienced when landing many times on a foot that is inverted and twisted inward. Landing on a foot that is inverted and twisted inward stretches the ligaments on the outside of the ankle and the knee, yet the muscles on the outer side of the limb absorb more shock. Conversely, the other limb, which is higher up the slope, experiences stress on the inner side. When this type of running is anticipated, the training program should include exercises to stretch and strengthen the appropriate soft tissues.

The training program that one uses can influence the way in which the body adapts to both speed and terrain. Many years ago, some runners used a training approach known as LSD—long, slow distance. Unfortunately, this training made them good only at running long distances slowly and led them to experience overuse injuries. Like machines, human bodies break down when subjected to the wearisome repetition of long-term continuous use.

One method of prevention is to vary the programs used. As sprinters have shown, fast running is about training the whole body. To some extent, of course, this means running fast, yet a large portion of the training program requires neither racing shoes nor a track. It should be no different for distance runners, who should exercise specific parts as well as their whole bodies. Hills and surfaces that are rough or uneven can all be faced with more confidence if the body is prepared, especially if certain weaknesses are known. For instance, cross country runners who know that they lose ground in thick mud can perform exercises and training drills to strengthen the thigh muscles needed to haul themselves through such conditions.

If you are unable to adjust to the speed and terrain that you encounter during your runs, then your performance level will be reduced and your enjoyment may disappear. With that pitfall in mind, this book presents guidelines that cover all these eventualities in order to help you adapt to the sort of running that you want to do and make yourself a better runner.

CONCLUSION

Runners who follow the basic tenets laid out in the training progression model presented in chapter 2 will succeed at running unless life gets in the way—which it invariably does! In other words, running performance is affected by external factors other than those discussed in this chapter; these additional influences can be characterized as life factors. For example, injuries happen despite following a well-conceived training plan. Work commitments consume the time needed for training. Family commitments make a mockery of one's best intentions for training. Stress (from either life or overtraining) produces cortisol, a hormone that (in small doses) helps the body deal with stress but can also limit or entirely shut down various body systems when stress is constant. Stress can also lead to sleep problems, digestive issues, and cardiac trouble. Although healthy training can help resolve stress, unhealthy training can exacerbate the problem.

The following chapters offer strength training exercises that will aid your running and help you stay healthy. When combined with the running training model provided in chapter 2, these exercises give you a well-conceived plan for running success. When you are mindful of the external factors addressed in this chapter that can affect your training, you can move forward with confidence in your ability to achieve your running goals.

4

FEET AND ANKLES

To pass the test of longevity, any structure must have a base that is strong, secure, and, preferably, wide. The perfect example of such a design is a pyramid. In contrast, a human being must make do with two stable lower limbs, augmented by relatively large feet, over a fairly narrow base.

The major weight-bearing bone of the lower leg is the tibia (figure 4.1). It is splinted by the thinner fibula, which becomes more relevant at the ankle, a hinged and curved joint of which the fibula forms the outer part. The muscles attached to these bones control the movement of both the ankle and the metatarsals and phalanges that form the foot. The ankle joint itself moves almost entirely in the anterior-to-posterior plane, but the seven bones that form the tarsus are positioned to enable both inversion and eversion of the foot at the midtarsal and subtalar joints. This capacity allows each foot to turn both inward and outward in order to accommodate uneven or slippery ground.

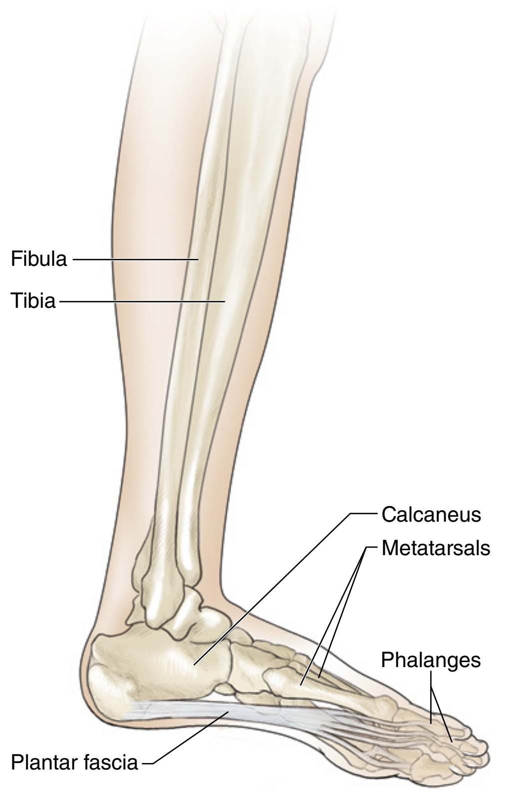


FIGURE 4.1 Bony structures and soft tissues of the lower leg and foot.

Just three bones on the undersurface of the foot make contact with the ground: the calcaneum (located under the heel) and the first and fifth metatarsal heads. Between this tripod of bones is located a complex consisting of the talus, cuboid, navicular, and three cuneiform bones, which lie in opposition to each other in such a way that they can be raised to form a longitudinal, or lengthwise, arch in each foot with the five metatarsal bones. All these bones not only change position to compensate for variations underfoot but also enable sideways movement by the foot. The tarsal bones form the apex of a bony arch, and when viewed from the ends of the toes they appear to rotate on each other to enable the foot to move in or out. This movement makes it possible for humans to walk and run on either the inside or the outside of the foot.

The power to push forward comes from the calves—specifically, the two muscles of the posterior compartment (figure 4.2*a*). The soleus is the deeper muscle and combines with the gastrocnemius to form the Achilles tendon, which is inserted into the calcaneum. Their contraction pulls this bone, and thus the whole foot, backward. A deeper layer of muscles provides flexion to the metatarsals and toes. These muscles—the flexor digitorum longus, flexor hallucis longus, and tibialis posterior—enable plantar flexion (downward pointing) of the foot and, because they cross several joints, of the ankle as well.

The anterior, or extensor, compartment of the leg (figure 4.2*b*) lies between the tibia and fibula and is surrounded by a relatively inelastic fibrous sheath. This compartment contains the tibialis anterior, extensor digitorum longus, and extensor hallucis longus. These muscles pass through the front of the ankle and are inserted into the tarsal and metatarsal bones and the phalanges of the toes in order to raise, or dorsiflex,

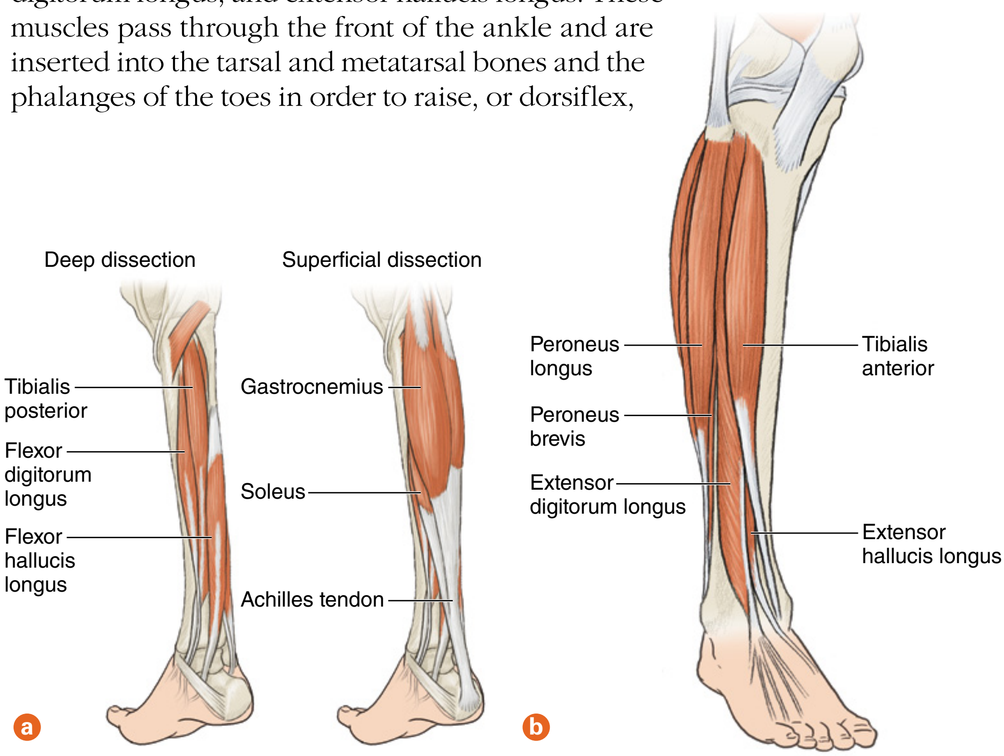


FIGURE 4.2 Lower leg and foot: *(a)* back and *(b)* front.

them. For most activities, this set of muscles does not have to generate the same power as do the posterior calf muscles; therefore, they are less developed and weaker. Further lateral stability in the ankle and rear foot is provided by the peroneal muscles, which arise from the fibula and pass around the lateral side of the ankle joint to be inserted into the outer metatarsals.

Very powerful forces are generated through the Achilles tendon, and injuries of this part of the anatomy tend to be very painful because of its well-developed nerve supply; they also tend to heal slowly because of poor blood flow in the area. Much the same can be said of the plantar fascia, which spreads from the front of the calcaneum and is inserted at the bases of the five metatarsals. The plantar fascia is an unyielding sheet of fibrous tissue whose weakest point is at the heel. If the foot is viewed two-dimensionally from the inside, the plantar fascia provides the horizontal base for the triangle completed by the tarsal and metatarsal bones.

These parts of the anatomy must be considered on a functional basis. We can facilitate such consideration by watching a slow-motion recording of a foot landing and taking off to help us understand the motion involved in each stride. The initial plant of the foot is known as the heel strike, after which the foot turns a little inward as the weight of the body progressively passes down the outer side of the foot before the landing is completed on the ball formed by the metatarsal bases. A few runners meet the ground first with their toes, sometimes because of an inability to dorsiflex sufficiently. This lack of heel strike may be due to genetic or structural causes. Most people, however, can run on their toes only for a very short time and distance because doing so requires the work of plantar flexion to be taken over by the comparatively weak toe flexors rather than the powerful calf muscles working through the pivot of the calcaneum—especially if dorsiflexion is limited.

Once the foot is flat on the ground, the movement continues in reverse. During takeoff, the heel lifts off first, rolls inward along the outer metatarsals, and ends with the final push-off from the ball of the foot. During this sequence, all of the involved muscles contract or expand in a regular rhythm, though not all at the same time.

At this juncture, we need to demystify the superstitions that have developed in regard to feet that are pronated or supinated. Movement within the foot involves three related but distinct elements: (1) at the subtalar joint, the foot inverts and everts, or turns inwardly and outwardly; (2) the midfoot is the site of abduction and adduction, in which movement occurs solely in the horizontal plane; and (3) at the forefoot, movement goes mainly up and down, either in plantar flexion or in dorsiflexion (which, somewhat confusingly, involves extension of the foot). Pronation involves a compound movement of these joints that includes eversion at the subtalar joint, abduction (i.e., outward horizontal movement) of the midfoot, and dorsiflexion at the forefoot. Supination, on the other hand, involves the opposite movements—that is, inversion at the subtalar joint, adduction of the midfoot, and plantar flexion at the forefoot. Some of these actions are exhibited in every stride by every foot. When they become excessive, however, the runner may overstretch internal ligaments linking the bones, which can lead to pain or injury.

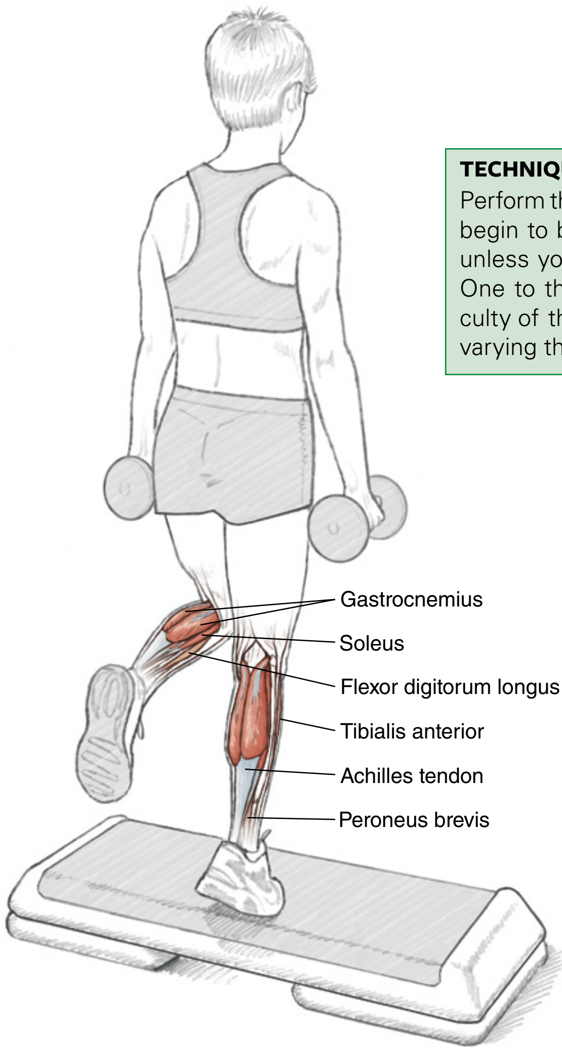
For instance, when excessive pronation occurs with the foot flat on the ground, the relatively weak longitudinal arch leans unduly inward and the toes point outward, thus stressing the tibia both by internally rotating it and by internally rotating (and stretching) the ligaments between the bones of the midfoot. In turn, this stress will reduce the ability of the foot's inverting muscles to perform efficiently. Supination involves the opposite action; that is, the outside of the runner's foot receives the force of landing on the ground. In this case, the tibia is externally rotated disproportionately, and the extra strain placed on the peroneal muscles may spread to the iliotibial band. (In chapter 11, we discuss how to minimize distress from overpronation and supination by choosing appropriate footwear.) Because of the internal strains that occur when the feet are excessively mobile, a severely supinated foot may prove too much of a handicap for a distance runner, though many of the fastest runners in the world have overcome this potential disability.

Two other anatomical variations involve runners who have high, rigid, longitudinal arches and may (but do not necessarily) supinate and those who have flat arches either with or without excessive pronation. For both of these types of feet, the lack of flexibility can constitute a mechanical disadvantage, and affected runners may therefore be slower than their potential otherwise suggests.

SPECIFIC TRAINING GUIDELINES

Some of the standing exercises presented here should or can be performed unilaterally, meaning with one leg at a time. This type of movement can strengthen the targeted muscles by recruiting all of the major leg muscles (weaker ones included) in order to establish balance while properly performing the exercise. Exercises that require stability also engage the core muscles of the abdomen, lower back, and hips in order to maintain proper form. Performing most freestanding exercises unilaterally helps ensure that the specific muscles targeted—and the core muscles recruited—develop strength and, with enough repetitions, muscular endurance.

SINGLE-LEG HEEL RAISE WITH DUMBBELLS



TECHNIQUE TIP
Perform the exercise until the calf muscles begin to burn; do not perform to fatigue unless you are performing only one set. One to three sets will suffice. The difficulty of the workout can be adjusted by varying the weight of the dumbbells.

Execution

1. Stand on a platform with the ball and toes of one foot touching the platform; the midfoot and the heel are not touching the platform. Hold the other leg at a 90-degree angle at the knee, from the hip, not touching the platform. Hold a dumbbell in each hand with the arms extending straight down along the hips and the sides of the quadriceps.

2. Maintain proper posture with an erect upper body stabilized by engagement of the abdominal muscles. Rise (using plantar flexion) on the foot that is touching the platform. Do not hyperextend the knee. The leg should be straight or slightly bent (at about 5 degrees).
3. Lower the foot (using dorsiflexion) back to the beginning position. Complete each set to tolerance, then repeat the exercise using the other leg.

Muscles Involved

Primary: Gastrocnemius, soleus

Secondary: Tibialis anterior, peroneus brevis, flexor digitorum longus

Soft Tissue Involved

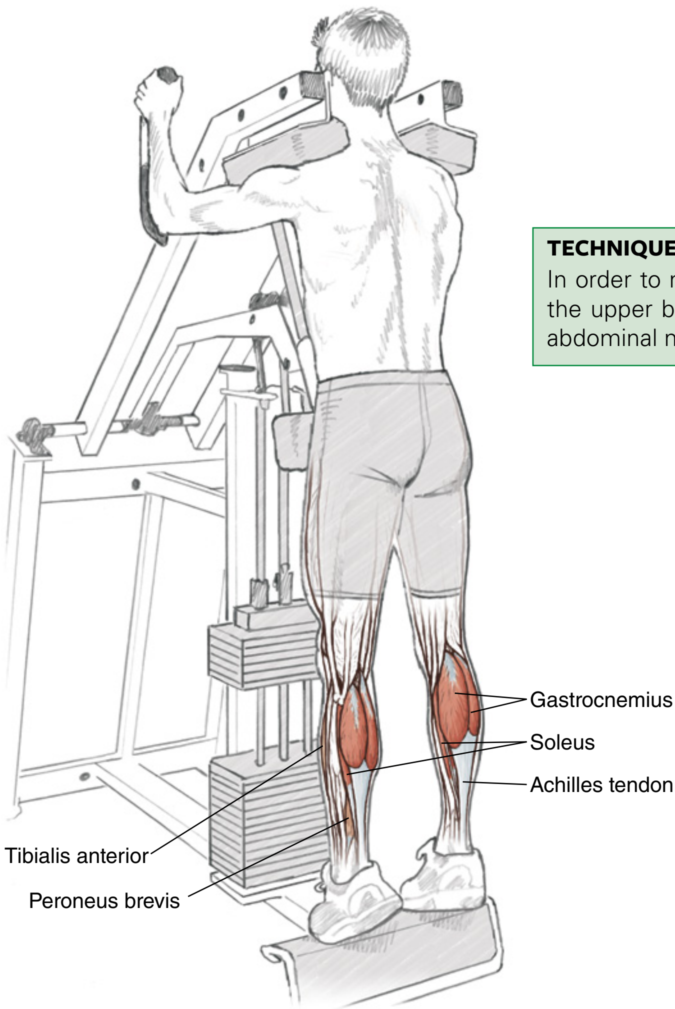
Primary: Achilles tendon

RUNNING FOCUS

The single-leg heel raise should be a staple of every runner's strength training regimen because it is easily performed, requires very little equipment, and can serve multiple purposes. Specifically, it can be performed either to develop strength, which helps prevent injury, or to rehabilitate in the case of injury to the Achilles tendon or calf muscles. The exercise should *not* be performed if a runner is still suffering the initial effects of the injury. However, it can be safely performed after the onset of injury if some healing has occurred as determined through either subjective evaluation of pain level or evaluation of an objective image (MRI).

As described in chapter 9, you can add value to this exercise for the calf and Achilles tendon by incorporating an eccentric, or negative, component—that is, lengthening the muscle. Eccentric motions provide value because the muscle can handle much more weight when contracting eccentrically. It has also been hypothesized that muscle is strengthened most when performing eccentric contractions and that eccentric contractions are better suited to develop a muscle's fast-twitch fibers.

MACHINE STANDING HEEL RAISE



TECHNIQUE TIP
In order to maintain proper form, hold the upper body erect and engage the abdominal muscles.

Execution

1. Stand under the shoulder pads of the machine with a slight flex at the knees. Maintain proper form by holding the upper body erect and engaging the abdominal muscles. The arms should be placed on the handles next to the shoulder pads. A light grip should be used.
2. Elevate the heels (using plantar flexion) until both feet are touching the platform with only the metatarsals and toes. The toes should be relaxed, and the emphasis should be placed on extension of the calf muscles.
3. Lower the heels until you feel a full stretch of the calves. Repeat.

Muscles Involved

Primary: Gastrocnemius, soleus

Secondary: Tibialis anterior, peroneus brevis

Soft Tissue Involved

Primary: Achilles tendon

RUNNING FOCUS

The standing heel raise is another exercise designed to strengthen the complex of calf muscles (gastrocnemius and soleus) and the Achilles tendon. It emphasizes the gastrocnemius—the larger portion of the calf—more than the soleus, but it does work the smaller muscle as well. This exercise can be done during the same workout as the single-leg heel raise in order to really fatigue the calf muscles. Alternatively, it can be used independently when the workout goal is to perform one exercise per body part.

The calf muscles and the Achilles tendon take on much of the shock absorption and deflection after heel strike. This impact becomes more pronounced when a runner races in lightweight shoes with a lower heel height than traditional trainers. To help minimize impact and aid in propulsion by moving the foot through its cycle, all runners should include exercises to develop calf strength in their training. These exercises can be performed during any stage of the running progression and should receive special emphasis during the racing phase if no injury has occurred.

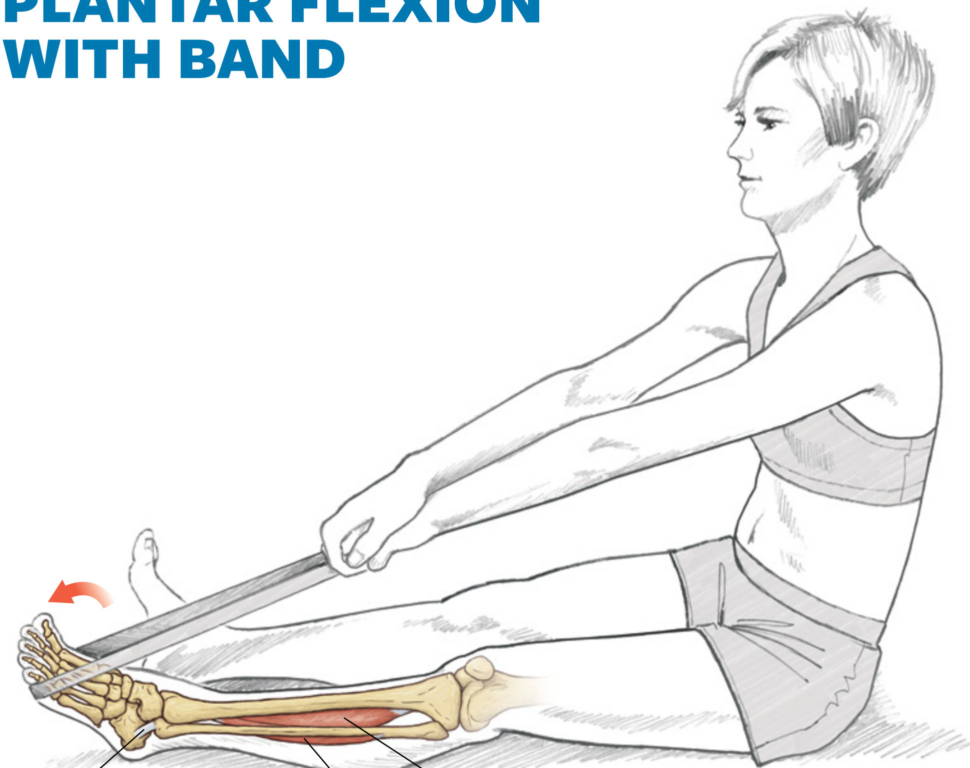
VARIATION

Machine Seated Heel Raise

Similarities abound between the parts of the anatomy affected by the standing heel raise and those affected by the seated heel raise. The two exercises are differentiated by the degree of emphasis placed on the soleus muscle. Specifically, when the heel raise is performed while sitting, the gastrocnemius muscle is less involved, thus allowing the soleus (despite its smaller size) to become the dominant calf muscle.

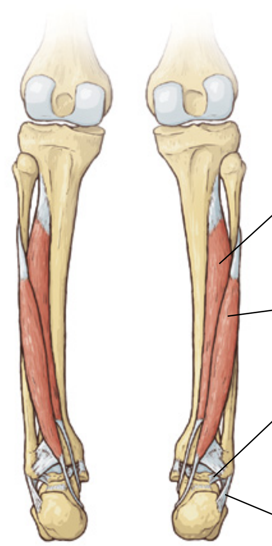
Strengthening the soleus aids in generating the propulsive force needed for the takeoff phase of the running gait cycle. It also helps runners who race (or work out) in racing flats to overcome calf pain and Achilles tendon strain during and following a race or workout. The lower heel height of the flat or spike forces the Achilles tendon to stretch more than it does when using running shoes. The extra stretch can be mitigated by strengthening and stretching the soleus muscle, thus helping prevent injury to the Achilles tendon.

PLANTAR FLEXION WITH BAND



Execution

1. Sit on the floor with the legs fully extended in front of the body. Extend a resistance band under the foot, wrapping it around the ball of the foot where the metatarsal heads are located. Hold the band in both hands. The band needs to be taut, with no slack, before the exercise begins.
2. Extend (plantar-flex) the foot to full extension.
3. At full extension, hold the position for one second before pulling the band back in a smooth, continuous fashion. The foot will be forced to dorsiflex and return to its initial position.
4. Repeat the push and pull of the exercise, adjusting tension throughout, until fatigue.



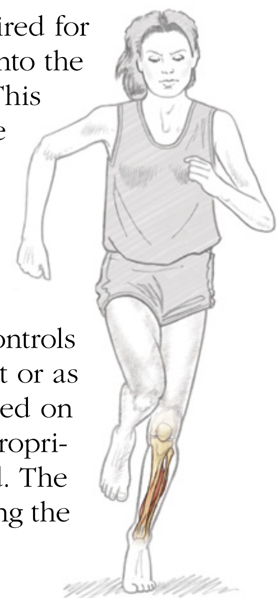
Muscles Involved

Primary: Tibialis posterior, flexor hallucis longus

Soft Tissue Involved

Primary: Posterior talofibular ligament, calcaneofibular ligament

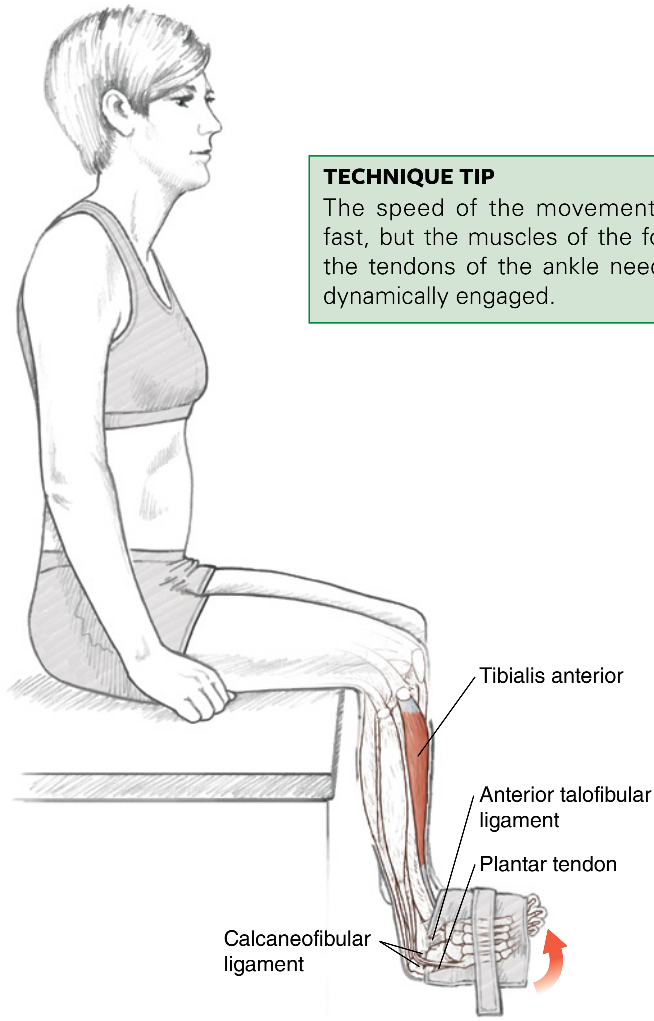
RUNNING FOCUS



As you may recall, chapter 3 discusses the adaptations required for running on various kinds of terrain and offers some insight into the roles played by the feet and ankles in running performance. This exercise promotes strength and flexibility of the foot and ankle in order to prevent injury when running on uneven terrain and aids in the support phase of the gait cycle.

Because this exercise is not weight bearing, it can be performed daily. It can either function as a rehabilitative exercise to overcome an ankle sprain or stand alone as an exercise to promote strength and flexibility. Because the exerciser controls the tension of the band, the exercise can be made as difficult or as easy as desired for each repetition. Emphasis should be placed on performing a smooth but explosive movement with the appropriate resistance provided by the tautness of the resistance band. The tautness can be easily adjusted by gradually pulling or releasing the ends of the band held in the hands.

DORSIFLEXION WITH ANKLE WEIGHTS



TECHNIQUE TIP
The speed of the movement is not fast, but the muscles of the foot and the tendons of the ankle need to be dynamically engaged.

Execution

1. Sit on a table with the knees bent and the lower legs dangling. Secure an ankle weight around the midfoot to provide appropriate resistance. The upper body is erect and the hands are by the sides, providing balance only.
2. In a smooth but forceful motion, the foot dorsiflexes (points upward and back) toward the tibia to full extension. The lower leg remains bent at 90 degrees and does not swing to aid the foot and ankle in moving the weight.
3. Gently lower (plantar-flex) the foot (which does not need to be fully extended); repeat to fatigue. Switch the ankle weight to the other foot and repeat the exercise.

Muscle Involved

Primary: Tibialis anterior

Soft Tissue Involved

Primary: Anterior talofibular ligament, calcaneofibular ligament, plantar tendon

RUNNING FOCUS

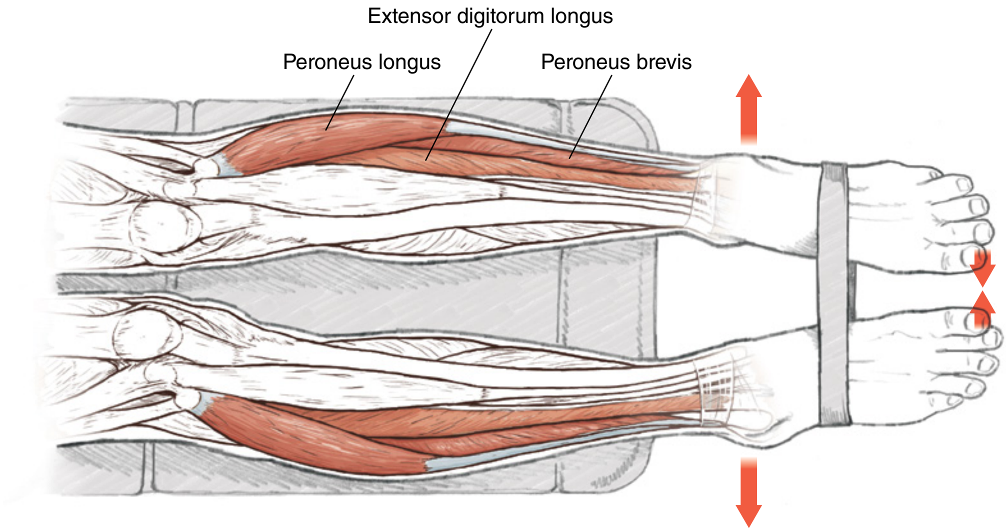
This is another non-weight-bearing exercise for the foot and ankle that can be performed daily, either for injury rehabilitation or to improve strength and flexibility. The weight of the ankle cuff can be varied to fine-tune the effect of the exercise. For example, performing fewer sets of fewer repetitions with a heavier weight emphasizes strengthening, whereas performing more sets of more repetitions with a lighter weight aids flexibility and endurance.

VARIATION

Dorsiflexion With Band

This exercise can also be done with a band, as in the plantar-flexion exercise. In addition, it can be done in an alternating fashion by first plantar-flexing the foot against the resistance of the tubing, then immediately dorsiflexing the foot when the tubing is pulled toward the body, until the foot is fully flexed and ready to plantar-flex again.

FOOT EVERSION WITH BAND



Execution

1. Sit on a weight bench with the legs fully extended so that only the Achilles tendons, ankles, and feet are off the bench. Support the body by placing both hands on the bench behind the body. Wrap an elastic band tautly around both feet, which are plantar-flexed with the soles down, leaving about 6 inches (15 cm) between the feet.
2. Rotate the feet inward, dropping the big toes and pushing outward with the feet against the resistance of the band. Hold for three to five seconds.
3. Relax the feet, rest for three to five seconds, and repeat.

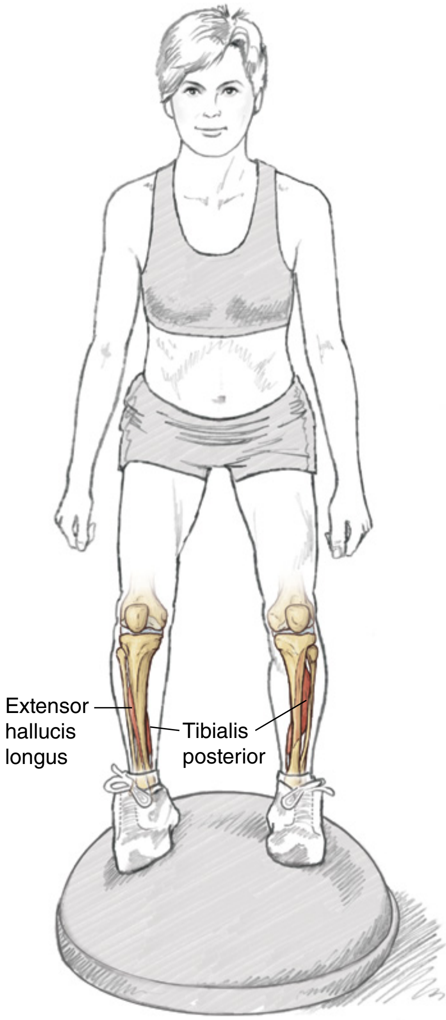
Muscles Involved

Primary: Peroneus longus, peroneus brevis, extensor digitorum longus

RUNNING FOCUS

As mentioned in the introduction to this chapter, pronation occurs as a result of movements on three planes, not just one. One of these movements is the eversion of the foot, which is controlled mainly by the peroneus longus during plantar flexion and by the peroneus brevis during dorsiflexion. This exercise is performed in the plantar-flexed position because it is an easier movement, particularly for a runner who is an overpronator. Underpronators, or supinators, benefit from this exercise because its motion is not the natural motion of their feet.

FOOT INVERSION ON BOSU



Execution

1. Step onto a properly inflated BOSU with the dome side up. Establish appropriate foot position to ensure a properly balanced body.
2. While standing on the BOSU with the feet in an inverted position, perform any standing exercise included in this book (see the Running Focus section for details).
3. Fatigue sets in quickly, and you can take a break as needed by stepping onto a flat surface between repetitions on the BOSU.

Muscles Involved

Primary: Tibialis posterior

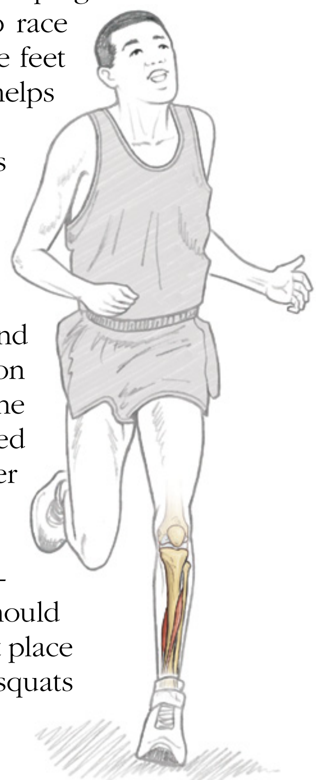
Secondary: Extensor hallucis longus

RUNNING FOCUS

BOSU devices are touted by fitness trainers as tools for developing balance and proprioception, which benefits runners who race and train off-road. In addition, the inverted position of the feet on the ball improves ankle strength and flexibility, which helps support each foot through the gait cycle.

The specific exercise performed while on the BOSU is less important than the emphasis placed on maintaining one's balance. Given the curvature of the dome, the feet are placed in an inverted position throughout the exercise. For example, performing squats with dumbbells would be a good exercise to promote strengthening of the feet and ankles in the inverted position. Another less dynamic option would be to perform dumbbell curls. Or you could do one set or multiple sets of each. The emphasis is on the inverted position of each foot, but combining this work with another exercise creates a time-saving compound movement.

The use of the BOSU also adds a twist to normal strength training exercises, thus making for a more varied and enjoyable strength training routine. However, some exercises should not be performed on the BOSU—specifically, exercises that place a lot of weight and torque on the knee joints (e.g., full squats with heavy weight).



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5

LEGS

When studying the parts of the anatomy engaged in running, we must consider the constituent soft tissues and bony structures to be connected. Movement of one element causes countermovement of another; moreover, the closer any two components are, the more they affect each other. For a simple example, consider knee flexion. In order to flex the knee, one must actively contract the hamstrings so that the quadriceps passively extends.

This connectedness is played out with every movement of the body, every breath, and every twitch, no matter how small. Nowhere is this truer than for the area that lies between the core and the upper legs, where the lower limbs merge seamlessly into the pelvis. Some of the pelvic muscles contribute to movement and stability of the legs, and the converse is also true. In another example, at the knee, muscles cross over two joints, thus influencing both the action and the strength of those joints. Because the legs bear the weight of the upper body (the part above the waist) and move it, over long distances in some cases, the lower limbs have evolved to maximize efficiency by combining strength and mobility.

The anatomy of the upper leg bone (figure 5.1), or femur, begins where it is inserted via the hip joint into the pubis and the ischium. The only other bone of the upper leg, the patella, which overlies the knee joint, functions as a pulley. Specifically, it runs in a groove at the lower end of the femur in order to guide the power of the quadriceps muscles, which extend the knee.

In fact, extending the knee is the primary function of the quadriceps group (figure 5.2*a*). It does so in the following manner: From the outside to the center line, the vastus lateralis, rectus femoris, vastus intermedius, and vastus medialis combine at the superior pole of the patella and straighten the knee joint with a pull through the patellar tendon on the upper part of the tibia. Contraction of this muscle group, the largest in the body, also pulls the knee toward the chest. This occurs because some of these muscles originate anteriorly to or above the hip joint, which means that their contraction causes them to act as a hip flexor. This dynamic is particularly relevant to sprinters, who can gain extra stride length with big contractions of the quadriceps. In a long-distance run, however, this high knee lift wastes energy; therefore, the hip and knee tend to move through much smaller ranges of motion when covering longer distances.

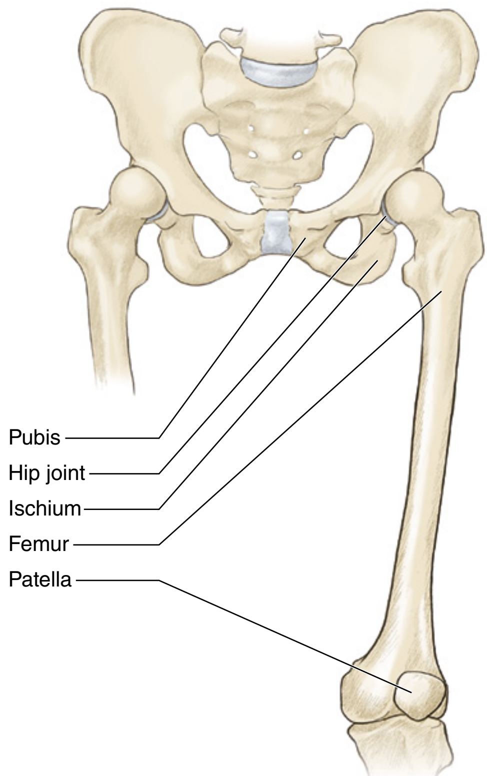


FIGURE 5.1 Bony structures of the upper leg.

Thus the role of the quadriceps in the running action is twofold, and the intent of both movements is to increase stride length (see figure 1.2). If the knee is fully extended and the quadriceps muscles simultaneously exert flexion to the hip, then not only is stride length maximized but also the added time in the air allows momentum already generated to propel the body farther forward.

Much the same goes for the hamstring muscles (figure 5.2*b*), which span the same two joints but act in a manner opposite to that of the quadriceps; that is, they extend the hip and flex the knee. The hamstrings—the semitendinosus, semimembranosus, and biceps femoris—have some congruity in the center of their bulk, having arisen from different points within the pelvis, but they separate behind the knee and are inserted into the rear of the tibia and fibula. Contraction of the hamstrings drives both the upper and the lower leg backward, a movement that tends to be exaggerated in a sprinter (see figures 1.3 and 1.4). Increased knee flexion would be inefficient, however, for a distance runner; instead, a greater percentage of the hamstring motion for a distance runner occurs at the hip.

It may be helpful to consider each full hamstrings group as two separate half muscles. This conception may sound paradoxical at first, but consider that the upper portion links over the hip joint as an extensor muscle, whereas the lower portion both flexes and limits extension of the knee. Of course, no physical

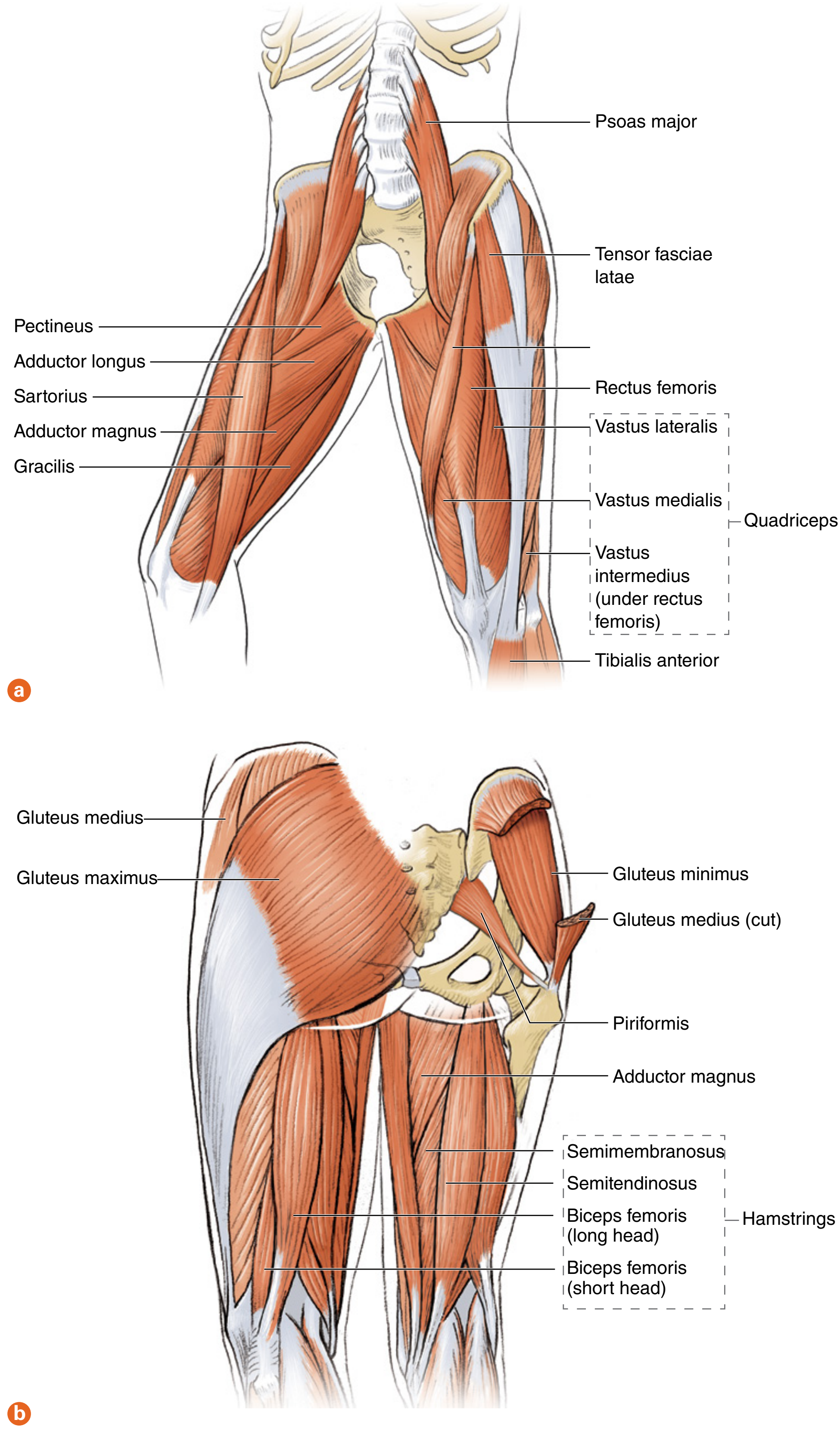


FIGURE 5.2 Upper leg: *(a)* front and *(b)* back.

distinction appears within the muscle groups when they are examined microscopically; the difference is purely functional. In distance runners, the hamstrings have a limited range of motion over both the hip and the knee joint, but their contraction is very powerful over the small angles through which they move.

Though it tends to be forgotten, the knee must also be able to twist—how else would a runner turn corners or cope with uneven terrain? The knee (figure 5.3) has two collateral ligaments, the medial collateral ligament, which connects the femur to tibia, and the lateral collateral ligament, which connects the femur to the fibula. These two single ligaments act together as a hinge to allow anterior and posterior movement. Rotation, however, depends on the crescent-shaped, slightly rubbery menisci, made of fibrocartilage that are placed between the femur and the tibia and spread weight through the knee joint. They also allow the bones to twist on each other. Each knee also possesses an anterior and a posterior cruciate ligament, which, placed in a cross-like shape, prevent excessive forward or backward movement of the femur and tibia on each other. Their main function, however, is to guide knee movement, and they play only a small part in knee stability, which depends almost entirely on the strength of the thigh muscle groups.

Thus thigh muscles need both strength and flexibility, each of which can be improved by exercise. Moreover, it is vital to maintain balance between the two, because being muscle-bound does little for pliability but lacking muscle bulk causes relative weakness.

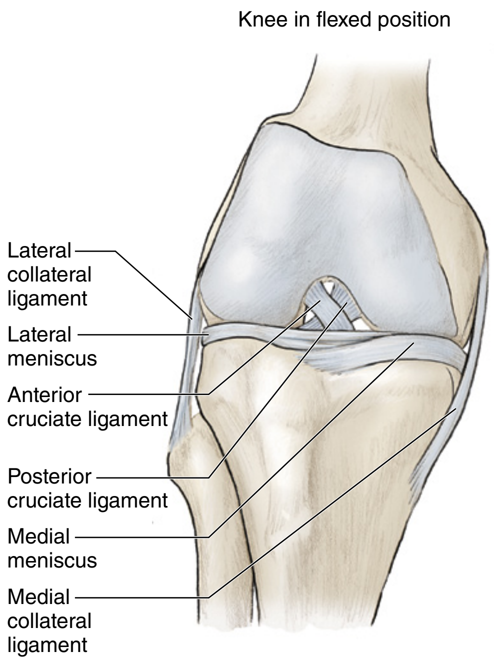


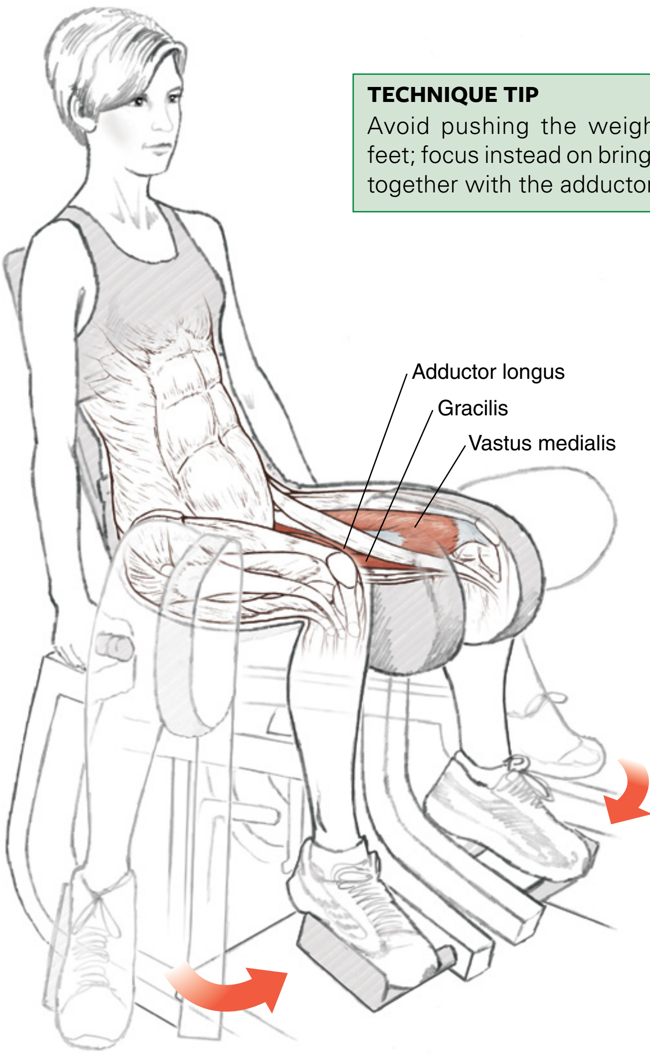
FIGURE 5.3 Knee ligaments and tissue.

SPECIFIC TRAINING GUIDELINES

Some of the following upper-leg exercises require you to take care to protect the knee joint. Because both the quadriceps and the hamstrings muscle groups attach to the knee—and because the knee joint twists in order to adapt to turns, uphills, downhills, and variations in terrain—the knee joint experiences ongoing stabilization and relaxation. Initially, the lunge exercises are difficult to perform, and care must be taken to perfect the motion with lighter weight before increasing the resistance. Machine-aided exercise helps protect the joint, but it is limited to a fixed range of motion that reduces its effectiveness as a functional exercise.

All of the exercises presented here for the upper legs can serve as good options for the introductory and strength (threshold) phases of training. However, during the final phase, which emphasizes $\dot{V}O_2$max training, you should perform only those exercises that have not led to excessive fatigue after previous strength-training sessions. To help you identify which exercises, weights, and repetitions to avoid, keep a log of training effects.

MACHINE HIP ADDUCTOR



TECHNIQUE TIP
Avoid pushing the weight with the feet; focus instead on bringing the legs together with the adductor muscles.

Execution

1. Assume a proper seated position with the machine pads on the insides of the knees.
2. Squeeze inward on the pads. The motion should be fluid and marked by consistent effort throughout.
3. Return to the original position by gradually resisting the weight.

Muscles Involved

Primary: Adductor longus, adductor brevis, adductor magnus, gracilis

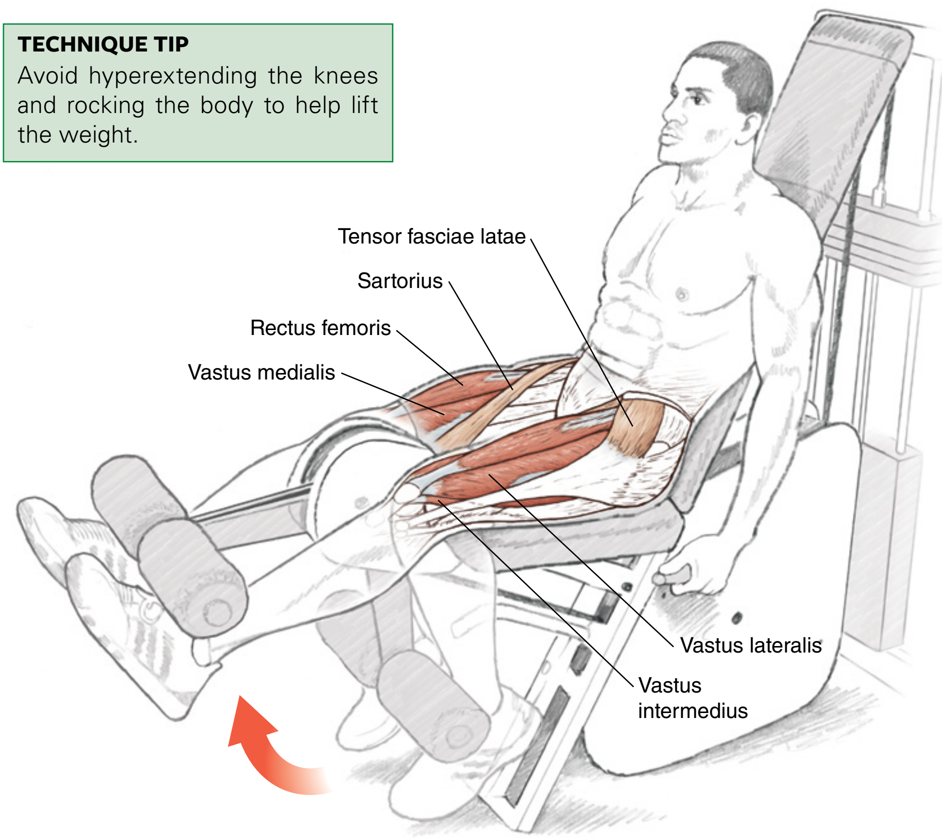
Secondary: Vastus medialis

RUNNING FOCUS

The adductor exercise can be used either in a strength development program or as part of a rehabilitative regimen that requires developing ancillary muscles without placing undue stress on the knee joints. Traditional therapy assumes that some knee problems are caused by imbalance in the four quadriceps muscles, which causes tracking issues for the patella. To prevent the patella from tracking too laterally, the adductor exercise strengthens the adductor muscle group primarily and the vastus medialis secondarily. Developing strength in the adductor group and the quadriceps muscles of the upper leg aids in the powerful extension used during the propulsive phase of the running gait. To prevent imbalances in the quadriceps, perform the abductor exercise on the same piece of equipment, as described in chapter 6.

MACHINE LEG EXTENSION

TECHNIQUE TIP
Avoid hyperextending the knees and rocking the body to help lift the weight.



Execution

1. Sit in the leg extension machine in the appropriate position. Keep the back straight and the knees in line with the fulcrum of the weight lever. Grasp the handles on either side of the seat, but do not squeeze them.
2. After choosing an appropriate weight, extend both legs (but do not hyperextend them) fluidly through a full range of motion.
3. At full extension, lower the legs gradually, resisting the weight while inhaling deeply.

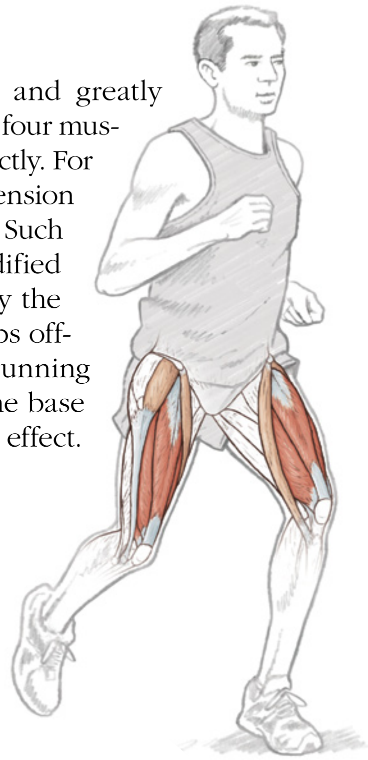
Muscles Involved

Primary: Quadriceps (rectus femoris, vastus lateralis, vastus medialis, vastus intermedius)

Secondary: Tensor fasciae latae, sartorius

RUNNING FOCUS

The machine leg extension is simple to perform and greatly improves quadriceps strength. It equally develops the four muscles of the quadriceps and helps the patella track correctly. For runners who suffer patellofemoral injury, the full extension needed for this exercise will unduly stress the patella. Such runners can develop the quadriceps by using a modified version of the exercise that involves a short arc (only the final 15 to 20 degrees of the full exercise), which helps offload the patella. The variation just described is not running functional, so it should be performed only during the base phase of training due to its general strength-building effect.



VARIATION

Machine Leg Extension With Short Arc

The leg extension with short arc is an excellent exercise for developing quadriceps strength in the presence of knee pain due to patellofemoral syndrome. The only drawback is that it is not involve the full range of motion; however, once the knee pain dissipates, the full-extension version of the exercise can be performed.

GLUTE-HAM RAISE

TECHNIQUE TIPS

- The closer to horizontal you can extend, the more you will work the hamstrings and glutes.
- Perform the exercise precisely, unhinging the knees simultaneously with extending the upper body in a single plane.

Execution

1. With initial help from your coach, adjust the pads of a glute-ham raise machine to fit your body.
2. Kneel on the machine and position yourself so that your shins touch the bottom pads and your quadriceps (upper legs) are perpendicular to your shins and pressed against the vertical pads. Your feet should extend behind you, between the two sets of pads at the rear.
3. Cross your hands in front of your chest. Extend and lower your upper body in a single plane (with the hips slightly forward of the pads) as you extend your knees through the rear pads. Extend your upper body to be horizontal to the ground.
4. Once full extension is reached, raise your upper body and lower your knees to the original position.

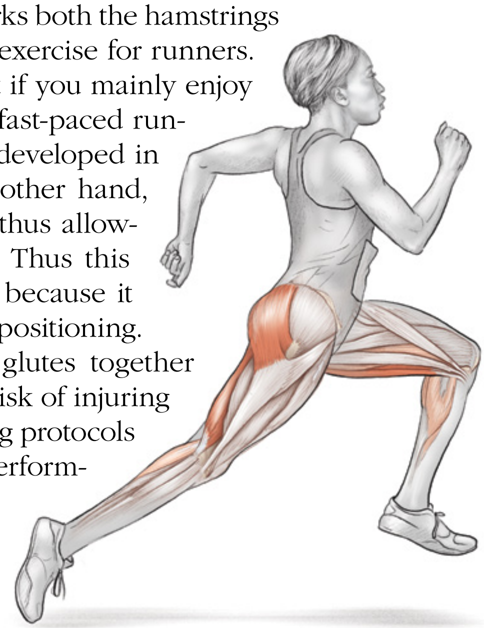
Muscles Involved

Primary: Gluteus maximus, gluteus medius, gluteus minimus, hamstrings (semitendinosus, semimembranosus, biceps femoris)

Secondary: Adductor magnus, gastrocnemius

RUNNING FOCUS

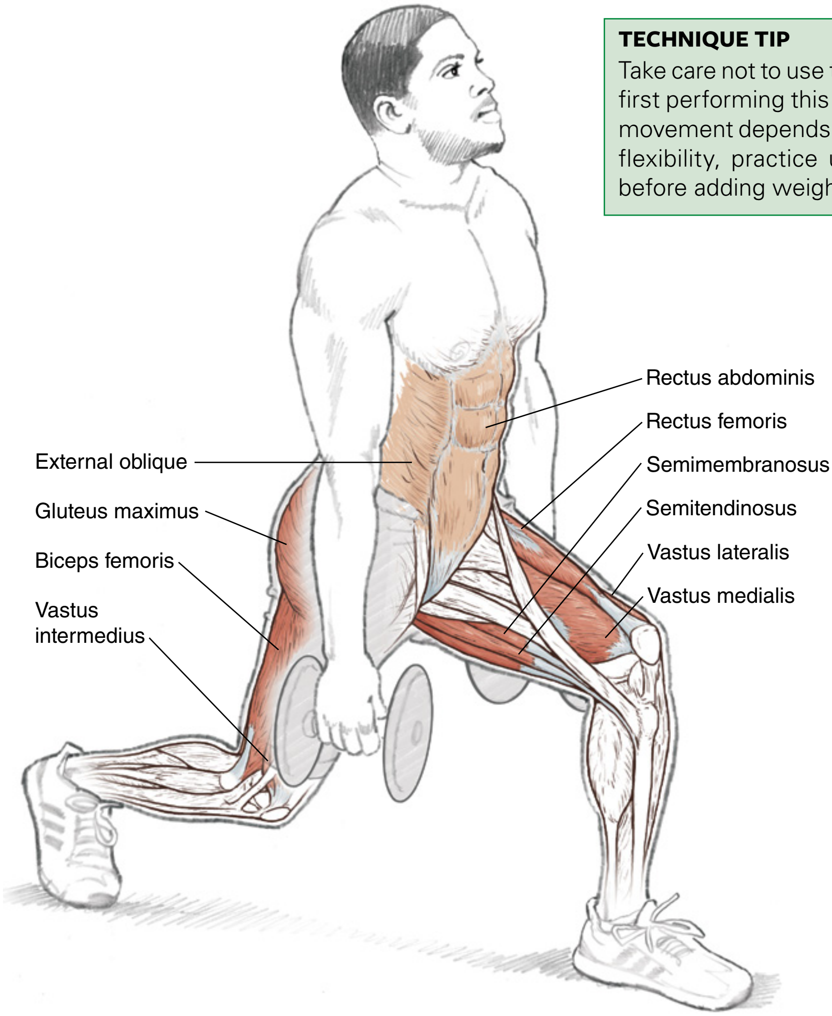
As its name indicates, the glute-ham raise works both the hamstrings and the glutes, which makes it a functional exercise for runners. The hamstring muscles help you go fast, but if you mainly enjoy recreational running then you perform less fast-paced running. The hamstrings also tend to be underdeveloped in most distance runners. The glutes, on the other hand, stabilize the core and aid in hip extension, thus allowing better body positioning while running. Thus this exercise gives you more bang for the buck because it aids in both speed development and body positioning. Moreover, developing the hamstrings and glutes together enables better symmetry, thus reducing the risk of injuring a weaker muscle group. Most strength training protocols call for this exercise to be completed after performing squats.



DUMBBELL LUNGE

TECHNIQUE TIP

Take care not to use too much weight when first performing this exercise. Because the movement depends heavily on balance and flexibility, practice using good technique before adding weight.



Execution

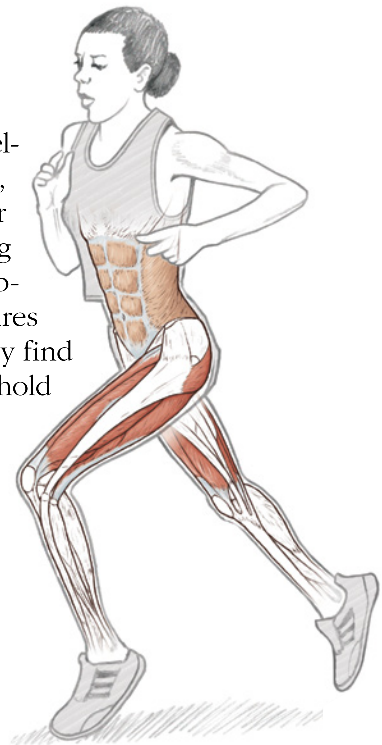
1. Stand with good posture and with the feet shoulder-width apart. In each hand, hold a relatively light dumbbell.
2. Take a small step forward with one leg, lowering your hips as you step so that the quadriceps of the stepping leg are parallel to the ground and the lower stepping leg is bent at the knee at a 90-degree angle. The rear leg provides balance.
3. After reaching parallel, return to the original position by pushing upward with the same leg that took the initial step. You can either alternate legs on each step or repeat the exercise for a full set of repetitions with one leg before performing it with the other leg.

Muscles Involved

Primary: Quadriceps (rectus femoris, vastus lateralis, vastus medialis, vastus intermedius), hamstrings (semitendinosus, semimembranosus, biceps femoris), gluteus maximus

Secondary: Rectus abdominis, external oblique

SAFETY TIP The possibility of knee injury is considerable here because of the knee's relatively vulnerable, unstable position while performing a difficult, anaerobic exercise. To avoid injury, do *not* allow the kneecap to extend past the toes of the lead foot.
Note: In a few runners with especially long femurs, it is difficult not to extend the kneecap past the toes. Practice the exercise in front of a mirror, and if your form is spot-on and your knee still extends past your toes, then so be it.



RUNNING FOCUS

Like the squat (a similar movement), the lunge develops strength throughout the core, the hamstrings, and the quadriceps. It is difficult, however, to master the proper form. Make sure you do so before adding weight. It is possible to use a barbell instead of dumbbells, but holding the barbell on the shoulders requires an unnatural hand position for runners, who typically find it more comfortable to keep the hands low and hold dumbbells.

This exercise fits nicely into the second, or strength (threshold), phase of training. It is functional and, with the added weight of the dumbbells, can develop significant strength.

VARIATION

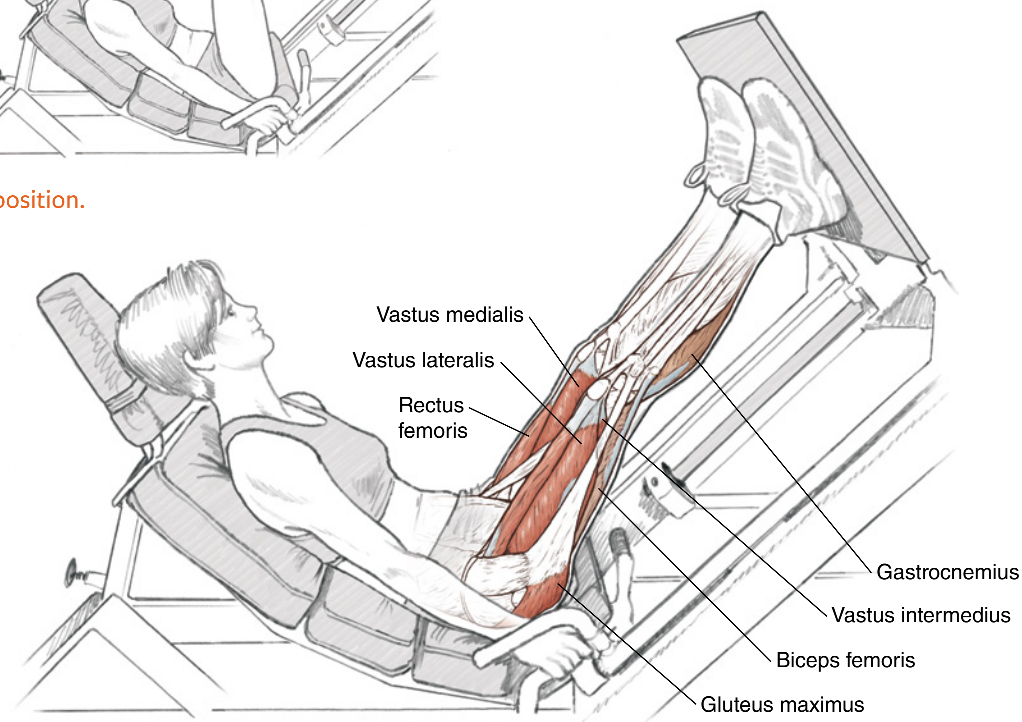
Lunge With Long Step

Taking a longer step strengthens the gluteus medius and gluteus maximus of the forward leg more than taking a regular step does. The longer step also stretches the iliopsoas and rectus femoris of the back leg.

MACHINE INCLINE LEG PRESS

TECHNIQUE TIP
Do not hurry the movement; doing so causes the weight to move past the full range of motion and bounce back to the legs.

Start position.



Execution

1. Sit with the feet placed less than shoulder-width apart on the bottom part of the footplate. The back and the head are pressed against the back pads. The safety catch should be on. Prepare the legs to support the weight, then flip the safety outward to render the weight active. Inhale.
2. Concentrating on the hips, glutes, and quads, extend both knees to move the legs fluidly to full extension.
3. Return to the starting position by gradually flexing the knees, thus allowing the weight to come back slowly to its original position.

Muscles Involved

Primary: Quadriceps (rectus femoris, vastus lateralis, vastus medialis, vastus intermedius), gluteus maximus

Secondary: Gastrocnemius, biceps femoris

SAFETY TIP This exercise allows you to use more weight because of its reliance on a machine; be careful, however, not to add too much weight before establishing proper form.

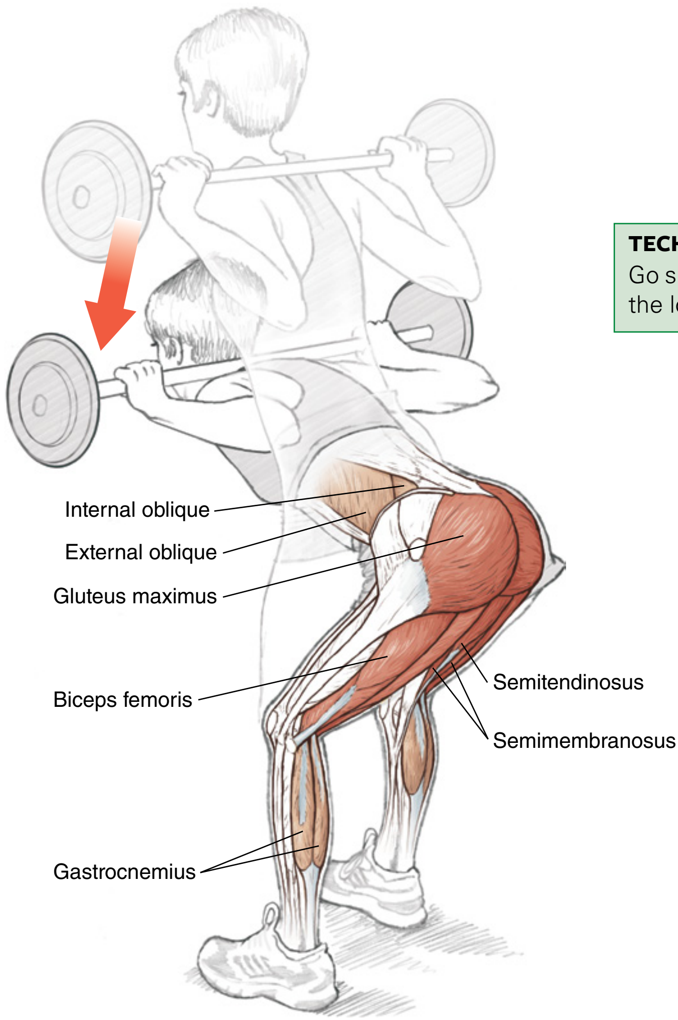
RUNNING FOCUS

This is a safe exercise that can quickly increase strength in the quadriceps and glutes because performing it on a machine allows you to use relatively heavy weights. Instead of intensively incorporating stabilizing muscles (abdominals and adductors), the exercise isolates the quads and glutes, thus strengthening both sides of the upper leg and thereby helping you avoid muscle imbalances and potential injury.

Altering foot position on the footplate changes the muscle groups affected. To incorporate the glutes to a greater degree, place your feet at the top of the footplate.

Because this exercise emphasizes the large muscle groups, it creates explosive power for runners. Therefore, it is best used by those who are training for shorter events such as a 5K or for track racing in sprints or middle-distance events. It is suitable for use during the introductory phase of training for all runners because it is a general strength exercise rather than a functionally specific one.

BENT-LEG GOOD-MORNING



TECHNIQUE TIP
Go slowly and feel the stretch of the lower back and hamstrings.

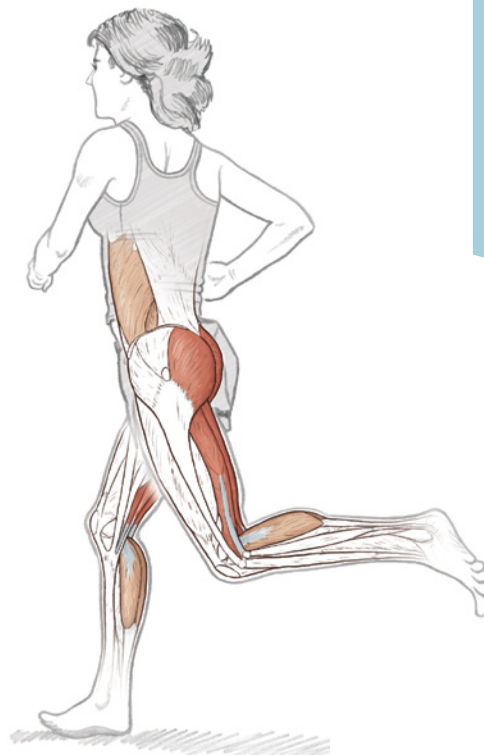
Execution

1. While standing with good posture and the feet shoulder-width apart, grasp a barbell with light weight across the shoulders.
2. Lower the torso by bowing at the waist. The back should be lowered in a single plane, maintaining the lumbar (lower-back) curvature. The glutes push outward during the motion. Inhale during the downward movement.
3. Return to the standing position by raising the torso while focusing on the rotation of the pelvis.

Muscles Involved

Primary: Hamstrings (semitendinosus, semimembranosus, biceps femoris), gluteus maximus

Secondary: Gastrocnemius, external oblique, internal oblique



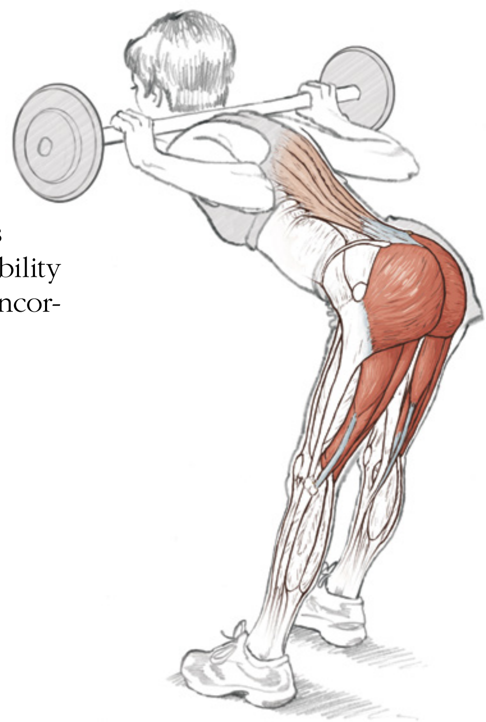
RUNNING FOCUS

Many distance runners complain that they feel chronic tightness in the lower back because of the mileage they have accumulated in training. In fact, the jarring impact of a heel strike combined with a lack of flexibility has caused many a runner to discontinue training and find another sport. How can you alleviate such a problem? The right exercises can help—for example, the bent-leg good-morning. Like most of the exercises presented in this book, this one is simple to perform and provides multiple benefits. Specifically, in addition to strengthening the hamstrings and glutes, it stretches these muscles, thus helping to loosen the connective tissue between the muscles and the bones of the lower back and the pelvis. This kinetic chain also affects the knees because a more supple lower back pulls less on the hamstrings, which in turn allows the kneecaps to track normally.

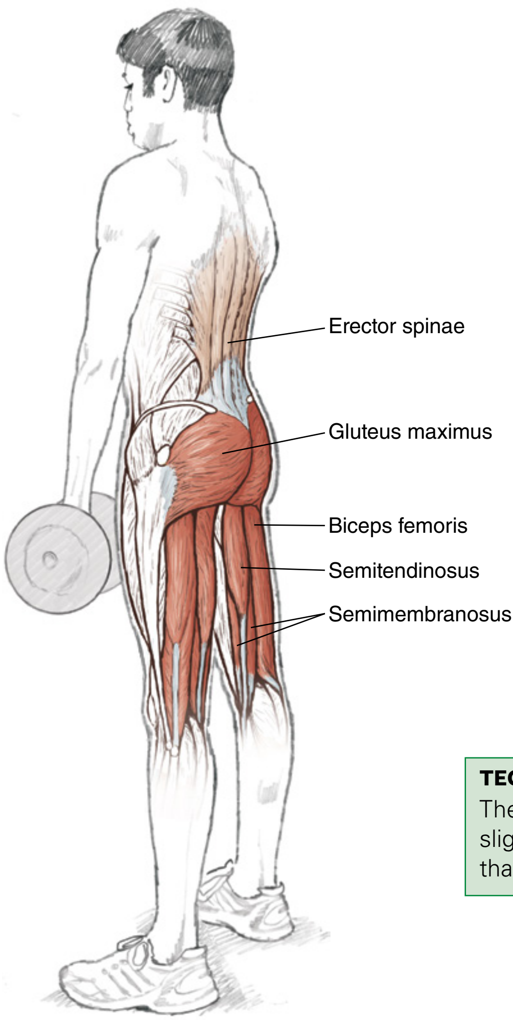
VARIATION

Straight-Leg Good-Morning

The good-morning can be performed with straight legs, but runners with chronically tight hamstrings should perform the exercise with bent legs because of the emphasis on hamstring flexibility. Once greater flexibility is attained, the straight-leg version can be incorporated.



DUMBBELL ROMANIAN DEADLIFT



Finish position.

TECHNIQUE TIP
The dumbbells should not reach the floor; the slight curve in the lower back should prevent that much movement.

Execution

1. Stand with the feet slightly apart, the legs slightly bent, each arm extended downward, and each hand holding a dumbbell in an overhand grip. There is a slight natural curve in the lower back.
2. Gradually bend at the waist, lowering your back in a single plane while maintaining the natural curve in the back. As you bend, the dumbbells almost scrape the quads and knees.
3. Once you can no longer lower the weight, return to the upright position.

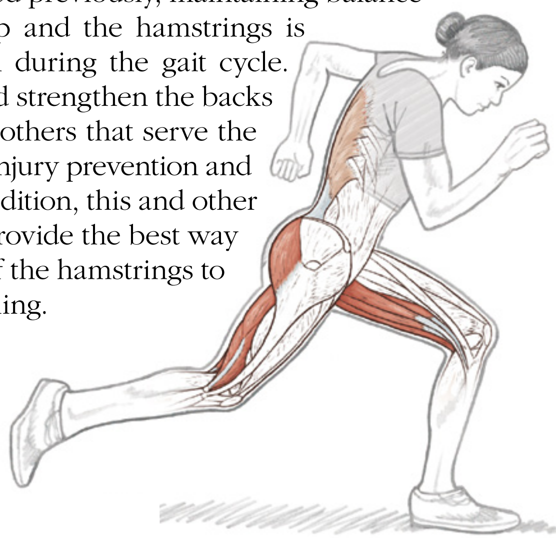
Muscles Involved

Primary: Hamstrings (semitendinosus, semimembranosus, biceps femoris), gluteus maximus

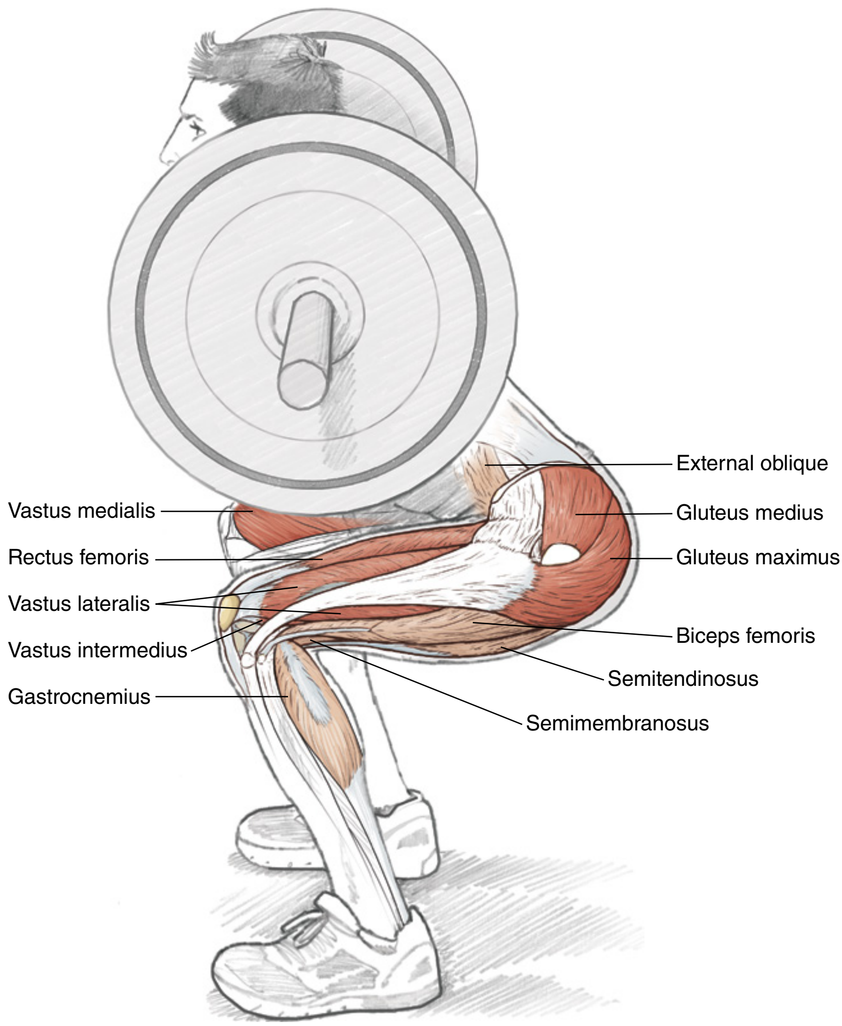
Secondary: Erector spinae (iliocostalis, longissimus, spinalis)

RUNNING FOCUS

This intense exercise emphasizes the upper legs—specifically, the hamstrings and glutes. It is extremely functional in that it works the muscles in the same way they work when running. As noted previously, maintaining balance between the larger quadriceps group and the hamstrings is the key to extension and propulsion during the gait cycle. Because this exercise helps stretch and strengthen the backs of the upper legs, performing it (and others that serve the same purpose) can almost guarantee injury prevention and therefore uninterrupted training. In addition, this and other exercises of relatively high intensity provide the best way to train the fast-twitch muscle fibers of the hamstrings to meet the demands of fast-paced running.



SQUAT



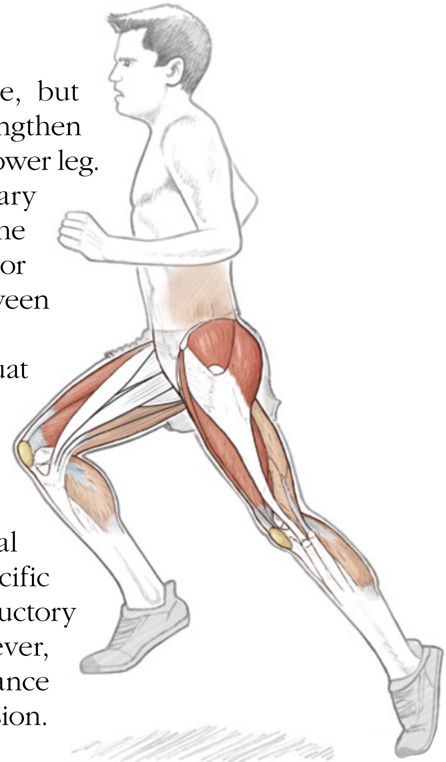
Execution

1. Using a squat rack, slide under the barbell and center it on the deltoid and trapezius muscles—not on the vertebrae of the neck. The feet should be shoulder-width apart and slightly splayed.
2. Inhale deeply, expanding the chest. Maintain the natural curve in the lower back while straightening up and lifting the barbell off the rack.
3. Establish proper position by taking a few steps backward, repositioning the feet properly, and reestablishing the accentuated curve in the lower back.
4. Look toward a point above head level and initiate the squat action by bending forward at the hips, which lowers the rear. When the thighs are parallel to the floor, straighten the legs and return to the initial position while exhaling.

Muscles Involved

Primary: Quadriceps (rectus femoris, vastus lateralis, vastus medialis, vastus intermedius), gluteus maximus, gluteus medius, gluteus minimus

Secondary: Hamstrings (semitendinosus, semimembranosus, biceps femoris), external oblique, gastrocnemius



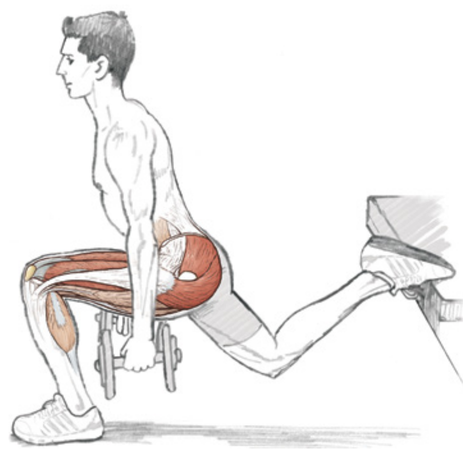
RUNNING FOCUS

The squat is primarily a quadriceps exercise, but because of its stability demand it also helps strengthen the core, the hamstrings, and the muscles of the lower leg. A heavy weight can be used, but it is not necessary to do so. Squats should be performed during the same session as the dumbbell Romanian deadlift or the good-morning in order to create balance between the front and back of the legs.

Like the machine incline leg press, the squat creates explosive power due to its emphasis on the large muscle groups. Therefore, it is best suited for runners training for shorter events such as the 5K or for track racing in a sprint or middle-distance event. Because it is a general strength exercise rather than a functionally specific one, it is normally emphasized during the introductory phase of training for distance runners; however, squats can aid all runners (sprinters and distance runners) at every phase of the training progression.

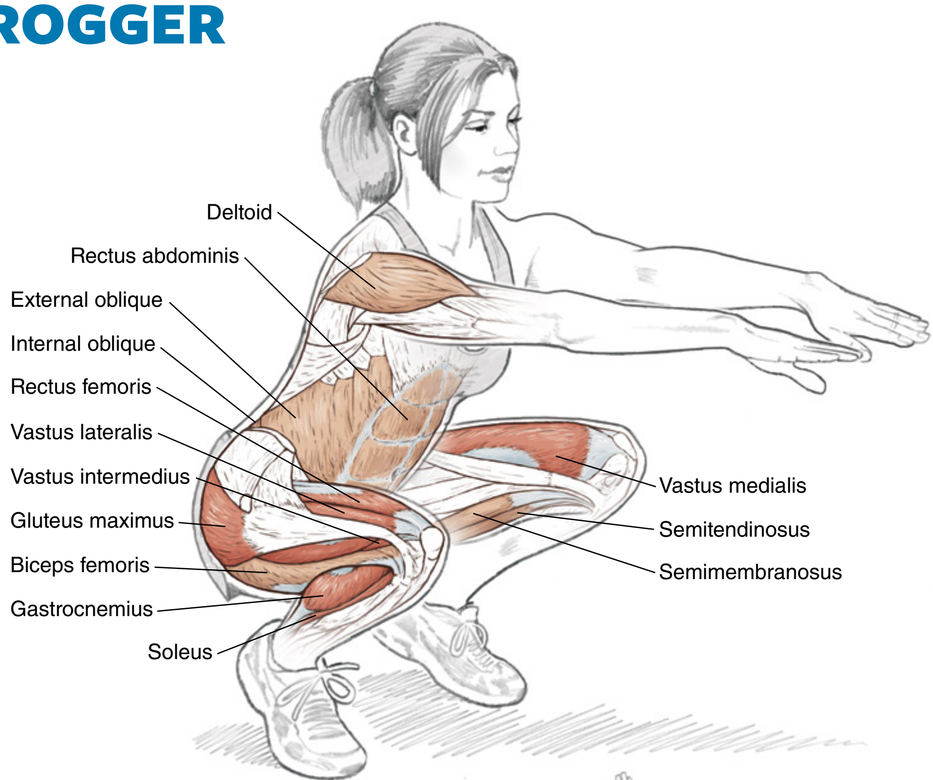
VARIATION

Single-Leg Squat With Dumbbells



This variation helps develop the adductor muscles of the inner thigh. Stand 2 or 3 feet (0.6 to 0.9 m) in front of a bench with a dumbbell in each hand. Place the top of one foot (with the shoelaces facing down) on the bench behind you. Lower your body until the forward leg is bent 90 degrees at the knee and the rear leg's knee almost touches the ground. Push back up using the quadriceps muscles of the forward leg. After performing a set of 12 on one leg, switch legs. The weight of the dumbbells does not need to be heavy; in fact, until good form is established, no added weight should be used.

FROGGER



Midair position.

Execution

1. Position the body in a full squat position with the feet slightly apart and the thighs horizontal to the ground. The lower back is gently arched, the head is centered, and the chin is slightly raised. The arms are extended in front of the body.
2. Inhale deeply while sweeping the arms backward and then quickly forward, thus developing momentum to help the legs explode from the full squat position at a 60-degree angle as the arms are thrown above the head. Upon reaching the apex of the jump, prepare to land. Upon landing, lower the body into the same position (full squat) as when the exercise started.
3. The movement will carry you slightly forward, thus emphasizing strength in both the vertical and the horizontal plane.
4. Upon reestablishing proper squat form, immediately repeat the jump.

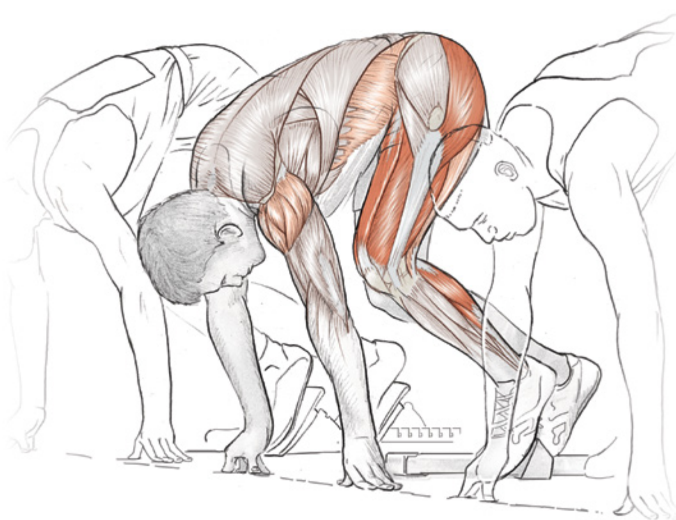
Muscles Involved

Primary: Quadriceps (rectus femoris, vastus lateralis, vastus medialis, vastus intermedius), gluteus maximus, gastrocnemius, soleus

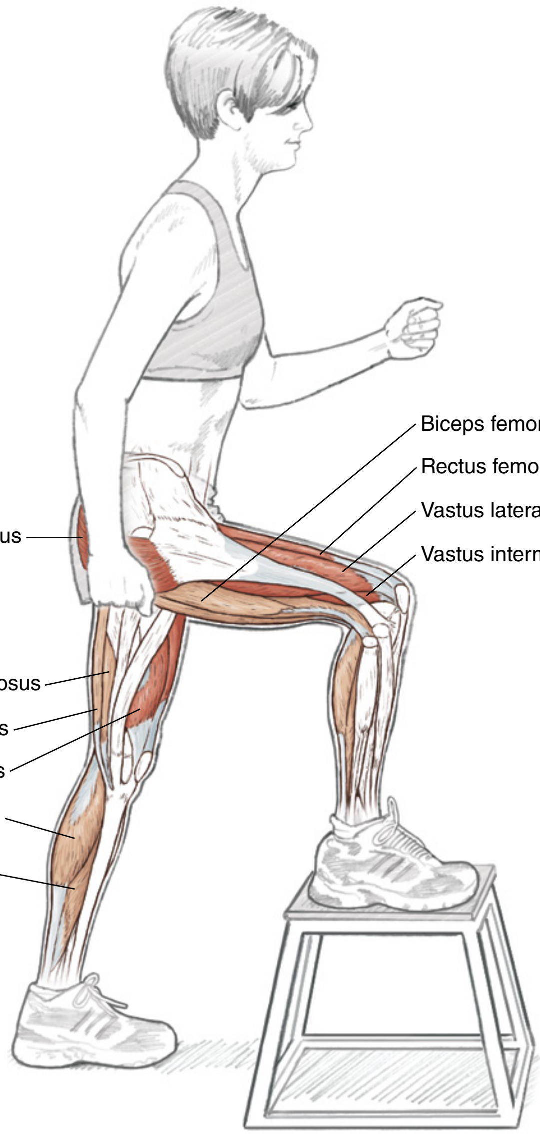
Secondary: Hamstrings (semitendinosus, semimembranosus, biceps femoris), deltoid, rectus abdominis, external oblique, internal oblique

RUNNING FOCUS

The frogger is a propulsive exercise that requires the athlete to explode from the start position by engaging the quadriceps, hamstrings, and glutes. It offers a practical application for sprinters (starting from a block) and, like all plyometric exercises, can also help distance runners increase running economy by strengthening the affected muscles, thus reducing energy consumption.



BOX STEP-UP



Execution

1. Stand with good posture while facing a plyometric box or weight bench. The box or bench should not be taller than knee-high.
2. Engage the quadriceps of one leg, lift that foot off the ground, and place it on the box or bench with the leg bent at a 90-degree angle at the knee. Step up with the other leg in the same manner so that you are standing on the box or bench.
3. Immediately step down by reversing the pattern used for stepping up. Complete a set following this pattern, then switch the lead foot for the next set.

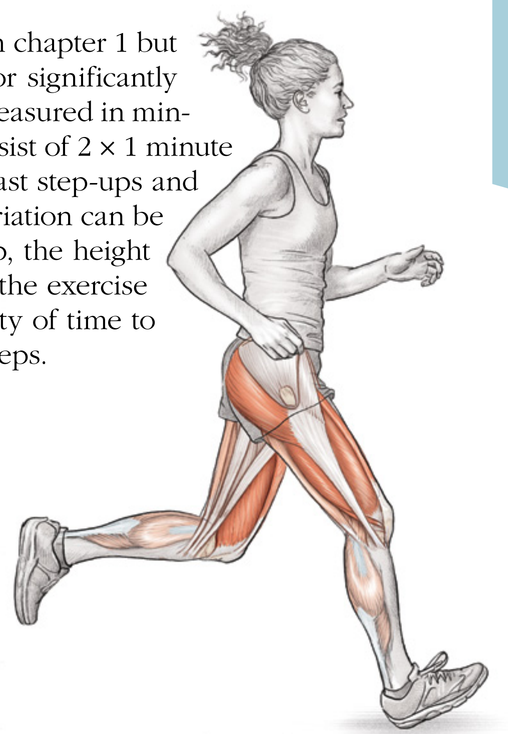
Muscles Involved

Primary: Quadriceps (rectus femoris, vastus lateralis, vastus medialis, vastus intermedius), gluteus maximus

Secondary: Hamstrings (semitendinosus, semimembranosus, biceps femoris), gastrocnemius, soleus

RUNNING FOCUS

This exercise mimics the A motion presented in chapter 1 but involves little impact and can be performed for significantly longer. Instead of counting touches, it can be measured in minutes. For example, a sample workout could consist of 2 × 1 minute of slow step-ups followed by 2 × 1 minute of fast step-ups and then another 2 × 1 minute of slow step-ups. Variation can be achieved by changing the speed of the step-up, the height of the platform, or the time interval. Although the exercise seems benign, five minutes of stepping is plenty of time to provide a good burn in the glutes and quadriceps.



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6

CORE

Running for pleasure did not play a large role in determining how the pelvis evolved in humans. The bones that form the pelvis exist principally to provide a protective structure for a developing fetus; of course, this need is not shared by men, who therefore have a narrower pelvis. In both men and women, however, the pelvis forms the platform from which the legs unite with the rest of the body and from which they have evolved to accommodate locomotion.

The pelvis is formed by six major bones: two each of the ilium, ischium, and pubis (figure 6.1*a*). These bones are solidly joined to each other, with no discernable laxity. Considerable movement is possible, however, where each ilium meets the lowest part of the spine—the sacrum—posteriorly at the large sacroiliac joints. This movement potential is most noticeable during childbirth, when hormonal influences cause the ligaments binding the joint to relax to such an extent that the joint may become subluxated, or partially dislocated. Therefore, any female who tries to run too soon after giving birth may experience considerable instability and the possible consequence of chronic pain and pelvic instability. Located above the sacrum are the five lumbar vertebrae, which play an important role in stabilizing the whole skeletal structure.

In addition to these two sacroiliac joints, each pubis is linked at the lowest point of the abdomen by the symphysis pubis. This relatively solid fibrous connection forms the pivot between the leg and the torso. As such, it constitutes the point of maximum force—and corresponding vulnerability—and is liable to damage in a slip or fall or as a result of chronic overtraining.

On the side of each ilium is located a depression that forms the hip, which is a ball-and-socket joint. The shape of the hip has evolved to combine maximum stability with the greatest possible range of movement. (The shoulder is similar but shallower and far more likely to experience dislocation under load.) The ball of the hip joint is formed by the head of the femur, and the socket is formed by the bony surround of the acetabulum. The socket limits movement of the joint under influence from the density and elasticity of the surrounding muscles and tendons.

If the pelvis is viewed from above as an oval-shaped clock, the two sacroiliac joints are located fairly close together at 11 and 1 o'clock, the hips are at 4 and 8 o'clock, and the symphysis is at 6 o'clock. If one of these joints is moved, then another must change position in order to compensate. This relatedness matters

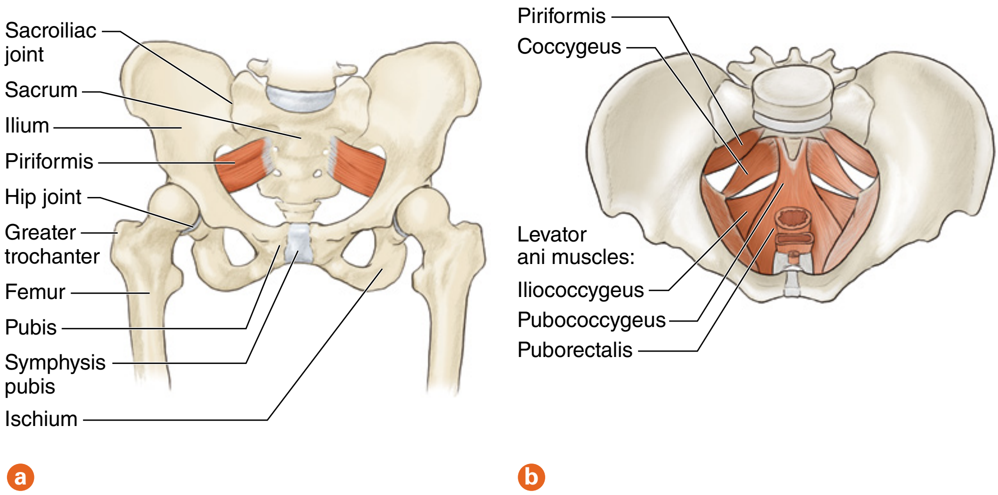


FIGURE 6.1 Pelvic bones and muscles: *(a)* bony structures; *(b)* pelvic floor muscles.

when running, because the pelvis swings from side to side and twists during the gait cycle, which affects the structures in and around it.

The floor of the pelvis is formed by the levator ani muscles (figure 6.1*b*), which, for those with some knowledge of Latin, do just that—lift the anus—and cradle the other internal organs that fill the pelvis so that they do not collapse through the pelvic outlet. The levator ani muscles require training and toning just like any other muscles, and weakness in them predisposes people to various degrees of incontinence. Because running increases the pressure inside the abdomen, any frailty in the levator ani may produce unwanted physical symptoms.

The other pelvic muscles fulfill a dual function of stabilizing and moving the legs from the foundation of their pivot at the hip joints. Stability is aided by some large ligaments, which are relatively inextensible but allow good breadth of movement. The iliopsoas muscles run on either side of the body from the lumbar vertebrae and the interior of the ilium, then pass through the pelvis, forming soft walls for the internal organs. They run on to the inside of the femur below each hip joint. Over the lumbar vertebrae, they are counteracted by the erector spinae muscles, which stabilize the spine externally. The iliopsoas muscles are strong flexors of the hips and pull the thighs up toward the abdomen.

The bulk of the buttock is formed by the glutei—three layers of muscle that slope down the outside of the back of the ilium at 45 degrees. Contraction of the outer layer, the gluteus maximus, extends and rotates the hip joint outward; this layer continues down the outside of the thigh as the tensor fasciae latae (see chapter 5). Beneath the gluteus maximus, the gluteus medius and gluteus minimus insert into the top of the femur at the greater trochanter. They pull the thigh outward (a movement known as *abduction*) with the hip joint acting as a fulcrum.

Alongside the gluteus medius lies the piriformis muscle, which stabilizes and abducts the hip joint. Runners with low back pain may well be suffering from piriformis syndrome, which likely derives from the muscle's close proximity to and irritation of the sciatic nerve.

Because the hip joint is so mobile, the forces produced by the muscles originating around and above the pelvis must be counteracted by forces from other groups of muscles. These, mainly the glutei, primarily pull the hip backward, abduct, and rotate it outward. The opposing muscles are those of the upper leg, which often fulfill more than one function. The hamstrings (semitendinosus, semimembranosus, and biceps femoris) all arise from the lower pubic bone (figure 6.2) and travel down the back of the thigh and behind the knee joint as its flexor (the lower limbs are discussed in more detail in chapter 5). Their upper-leg function is to extend the hip backward. The three adductors (adductor magnus, longus, and brevis) and the gracilis all pull the thighs together. They arise from the inside the pubis and are inserted along the inner border of the length of the femur. Like the iliopsoas, the rectus femoris and the other quadriceps muscles also extend over the hip joint. When they contract, they exert a flexing action on the femur.

Muscles may be distinct entities, but they often merge into one another and can be difficult to separate when dissected. Because the running action is repetitive, even muscles whose functions differ only slightly may oppose each other and produce negative frictional forces. This condition can result in the formation of a small fluid-filled sac called a *bursa*, the largest of which is found over the greater trochanter and known as a *trochanteric bursa*. It may become inflamed and sore, especially if a change is made in the quality or quantity of training.

Returning to the pelvis and its adjacent organs, the abdomen (unlike the chest) does not have a bony architecture to stabilize it. The lumbar vertebrae maintain vertical height, but the responsibility for stability falls to the abdominal contents, which exert counterpressure on a surrounding circular wall of muscles. This

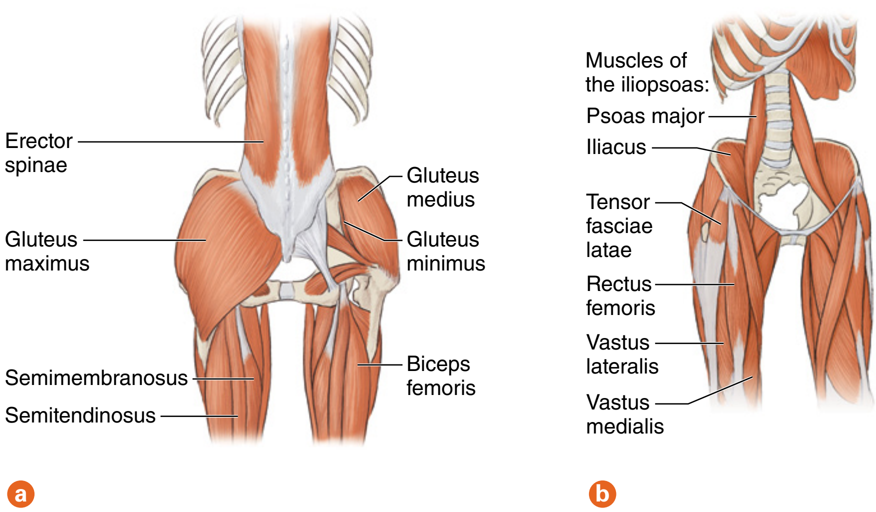


FIGURE 6.2 Lower core through upper leg: *(a)* back; *(b)* front.

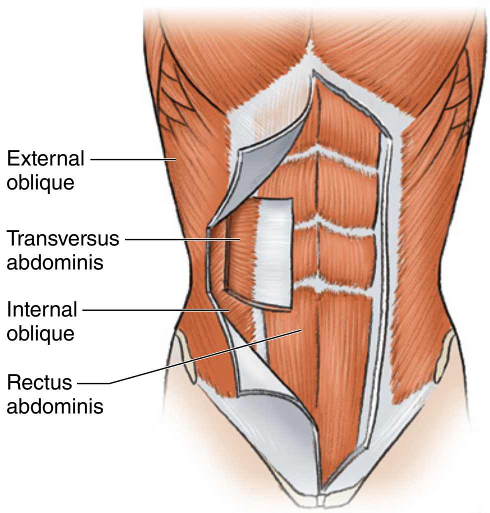


FIGURE 6.3 Rectus abdominis and surrounding muscles.

wall is formed by the rectus abdominis, which extends from the base of the rib cage centrally down to the pubic symphysis and pubic bones (figure 6.3).

Outside this wall and lying diagonally are the external and internal obliques and the transversus abdominis muscles, which fulfill three functions: abducting and rotating the trunk, flexing the lumbar and lower thoracic vertebrae forward, and containing the abdomen. When running, these muscles alternately lengthen and shorten as the pelvis not only moves from side to side but also twists, rises, and falls relative to the surrounding body parts. They also aid high rates of respiration by working in conjunction with the diaphragm and ribs; this role is particularly noticeable if the runner is reduced to panting. They may also be required to play these roles at the same time, and they perform better if they are well trained.

In contrast, the lower-back muscles and lumbar vertebrae serve in more of a passive, stabilizing capacity during running. First, they must maintain an upright posture, tempered by the need to accommodate for hills, where the upper body must lean backward or forward to counteract gravity's potential to upend the runner. In addition, the encircling musculature must allow rotation, body tilt around corners, and lateral movement on any diagonally sloping surface; in order to do so while maintaining stability, they contract and expand as needed. Of course, these complex movements coexist with all of the other variations in posture that occur as the legs move, the lungs breathe, and the abdominal contents shift to accommodate ingested fluid and nutrients during the run. Intrinsic strength, particularly of the muscles that surround the lumbar vertebrae, should be considered essential in every runner because any weakness is liable to escalate into other areas.

PELVIC TILT

Like clothing fashions, running injuries seem to go in and out of vogue. Currently, injuries resulting from glute inactivation and a posteriorly or anteriorly rotated pelvis are regularly discussed in running forums and during injury sessions at running clinics. More generally, the old paradigm holding that most running injuries are caused solely by improper foot biomechanics has been supplanted by discussions of the gluteal muscles, pelvis, and hips.

According to many running experts, most problems arise due to a weakness of the gluteal muscles (in particular, the gluteus maximus and gluteus medius). Once the functioning of the gluteal muscles is compromised, other muscles—the quadriceps and the iliopsoas (consisting of the psoas major and the iliacus), which is a hip flexor—are recruited to stabilize the pelvic region. This emphasis on the iliopsoas can be viewed as a major culprit in creating an anterior pelvic tilt due to the fact that the iliopsoas functionally shortens (becomes tight) due to overuse from running—specifically, from the repetitive hip flexion involved. A posterior pelvic tilt, on the other hand, is caused by a weak iliopsoas, which requires secondary movers such as the tensor fasciae latae and rectus femoris to do the work.

Incorrect pelvic tilt can contribute to injuries that seem unrelated to the pelvis. For example, one theory holds that dysfunction of the pelvis can result in patellofemoral syndrome. In this theory, the hamstrings are overrecruited and lengthened, which abnormally loads the knee capsule and the anterior ligaments, thus causing pain in a joint 18 inches (45 cm) away from its source!

A more common complaint involves destabilization of the hip complex (lumbar spine, pelvis, and musculoskeletal components of the hip) that results in pain or discomfort in the core. Essentially, in this case, the hip fails to function as designed because muscles in the kinetic chain are weak or compromised, which forces compensatory nonprimary movements of the muscles engaged in running. For example, the hamstring muscles (in the back of the leg) perform certain roles in running biomechanics; they are used primarily in knee flexion and secondarily in hip extension. However, when the gluteus medius or gluteus maximus is "turned off" and a runner still wants to run, the hamstrings must function fully in secondary roles for which they are not best suited as primary movers. If a dysfunctional movement pattern is prolonged, it causes injury due to overuse.

Pelvic tilt abnormalities can be addressed simply and logically by performing exercises that strengthen the posterior chain muscles—specifically, the glutes and hamstrings. Examples included in this chapter include the bridge with leg kick and the sliding leg curl. However, although posterior chain exercises can unquestionably aid good running posture, and hence performance, overemphasizing them can lead to problems, as with any exercise imbalance. Examples include tight hip flexors and pelvic floor dysfunction, which is typically related to childbearing but can also occur in female runners who have not given birth. The mere fact of having strong muscles doesn't mean that they are functional. To attain proper running form, emphasize balancing the large anterior movers (abdominals) and the posterior movers (glutes).

Pilates

Pilates is an exercise regimen designed to improve physical strength, flexibility, and posture and to enhance mental awareness. It emphasizes six key concepts: concentration, centering, control, breathing, precision, and flow. The exercises can be performed either on a mat or on a reformer machine designed by founder Joseph Pilates.

Pilates for Runners

As compared with older runners, young runners tend to be physically stronger and more flexible and to have better posture and flow (that is, a more natural running rhythm). Older runners, on the other hand, tend to have better concentration skills, breathing patterns, and precision than younger runners. Therefore, Pilates would seem potentially beneficial to all runners—but how, exactly? Let's consider the question in light of the six key concepts of Pilates.

Pilates requires practitioners to use concentration by focusing on small movements. In a race or running workout, such focus is invaluable because it keeps the runner present in the moment.

Pilates also emphasizes centering, or generating all movement from the powerhouse—the area located between the lower ribs and the pubic bone. Each exercise in a Pilates session works the targeted muscles: the pelvic floor muscles (levator ani and coccygeus), the central core muscles (obliques, rectus abdominis, quadratus lumborum, and transversus abdominis), and the gluteus maximus. These muscles are integral in stabilizing the core during running.

The control aspect of Pilates dovetails with both the concentration and the centering pieces. By concentrating on a small, specific movement originating from a very specific part of the anatomy centered at the core, all runners can learn to control their bodies during the dynamic running movement. The ultimate goal is to keep the core in a cylindrical shape and at a slight forward angle originating from the feet (not the waist).

The breathing patterns established in Pilates practice also aid the runner. By emphasizing full inhalation, and expanding the bellows, both running and Pilates focus on efficiently bringing fresh oxygen into the lungs (and from there into the circulatory system) and disposing of CO_2 through exhalation.

Precision in Pilates movement results from the fusion of the three Cs: concentration, centering, and control. The same holds true for each step in running. As you move through the gait cycle, each movement should be precise but not mechanical. This approach allows the runner to achieve a flow, which is the final element developed in Pilates.

Classical and Contemporary Pilates

Classical Pilates follows the specific instructions and order devised by Joseph Pilates, whose students and devotees have passed down the classical methodology to current teachers. Classical protocol exists for both mat and reformer classes.

Contemporary Pilates practice differs from classical Pilates in the sense that it incorporates current ideas taken from physical therapy and biomechanical study. The movements are still based on Joseph Pilates' teachings but have been updated to reflect current or contemporary understanding of the body and the stresses of the modern world (such as bad posture derived from sitting hunched in front of a computer screen). Contemporary Pilates also promotes a neutral pelvis—a slight, natural arch in the lower back—whereas classical Pilates teaches a posterior tilt of the powerhouse.

Both schools offer benefits to most students, including runners. Be aware that the term *contemporary Pilates* can be used to encompass any Pilates-like movement, which may or may not accord with what the founder intended. The key question, for either school, is whether the movement helps one achieve its goal.

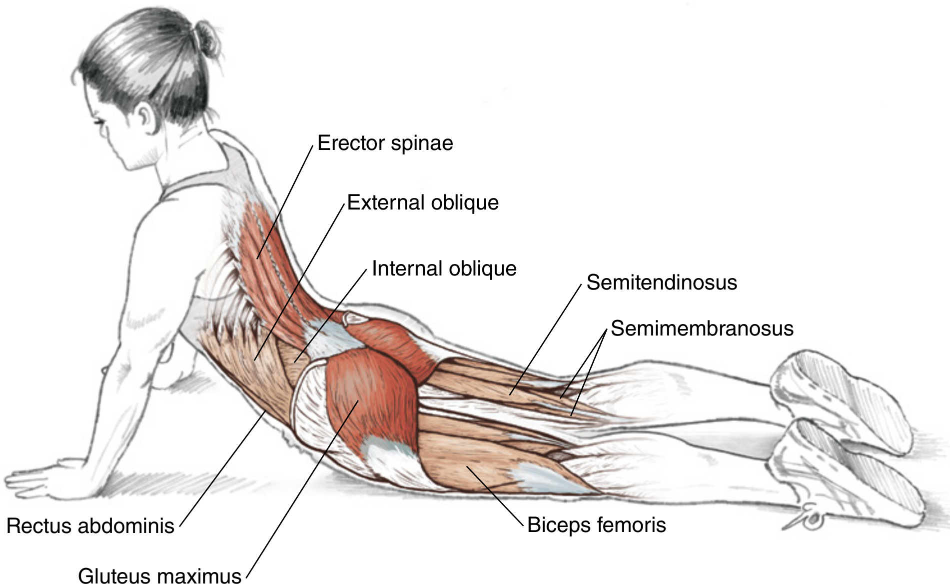
SPECIFIC TRAINING GUIDELINES

For the core exercises that require the movement of body weight only, multiple sets can be performed with many repetitions. All body-weight exercises should be performed slowly and deliberately. Without extra resistance, the emphasis should be placed less on moving weight and more on making perfect movements.

The use of high repetitions offers a great way for a runner to develop muscular endurance, which benefits long-distance runners; however, the strength needed for power comes only from using heavier resistance. Thus, choosing what weights to use (when applicable) and how many (or few) repetitions to perform depends on the goal of the workout and, in a larger sense, on the runner's performance goal.

Core exercises should be performed at all stages of the training progression. Many of these exercises use only body weight and therefore it is recommend that they be performed three or four times per week.

BACK EXTENSION PRESS-UP



Execution

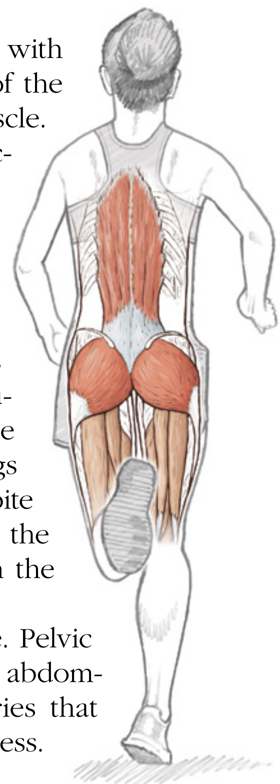
1. Lie prone on the floor with the arms in the push-up position and the legs outstretched. Keep the body rigid and in a straight line.
2. Press up with the arms only until the torso is off the floor. Hold this position for 10 to 15 seconds, breathing throughout.
3. Lower the arms, bending at the elbows, and return to the original position.

Muscles Involved

Primary: Erector spinae (iliocostalis, longissimus, spinalis), gluteus maximus

Secondary: Hamstrings (semitendinosus, semimembranosus, biceps femoris), rectus abdominis, external oblique, internal oblique

RUNNING FOCUS

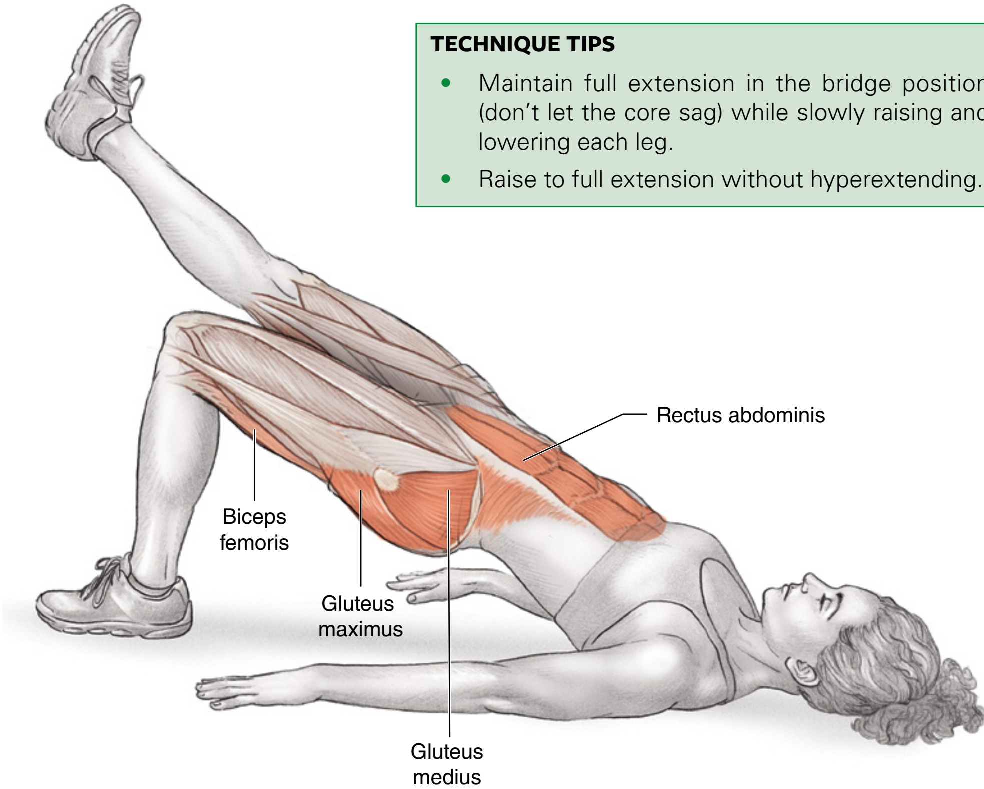


This is a very simple exercise that should not be confused with the push-up. It helps strengthen the muscles and tendons of the erector spinae, the antagonists for the rectus abdominis muscle. The exercise also strengthens and stretches the support structure of the sacral and lumbar spine. In this way, it helps the pelvis rotate and twist properly and mitigates forward tilt of the pelvis, which can result from performing too many abdominal strengthening exercises and can lead to imbalance between the abdominals and the muscles of the lower back.

Unfortunately, emphasizing the core exercises sometimes devolves into emphasizing the abdominals to the near exclusion of the glutes and the lower-back muscles. In the absence of strong glutes and a supportive lower back, the hamstrings may be unable to generate sufficient muscular power despite their having been strengthened properly. Essentially, then, the strongest muscles are only as strong as the weakest link in the kinetic chain allows them to be.

Proper movement of the pelvis is critical in the gait cycle. Pelvic misalignment, which may result from imbalance between the abdominal muscles and the lower-back muscles, can cause injuries that impede running performance despite good cardiothoracic fitness.

BRIDGE WITH LEG KICK



TECHNIQUE TIPS

- Maintain full extension in the bridge position (don't let the core sag) while slowly raising and lowering each leg.
- Raise to full extension without hyperextending.

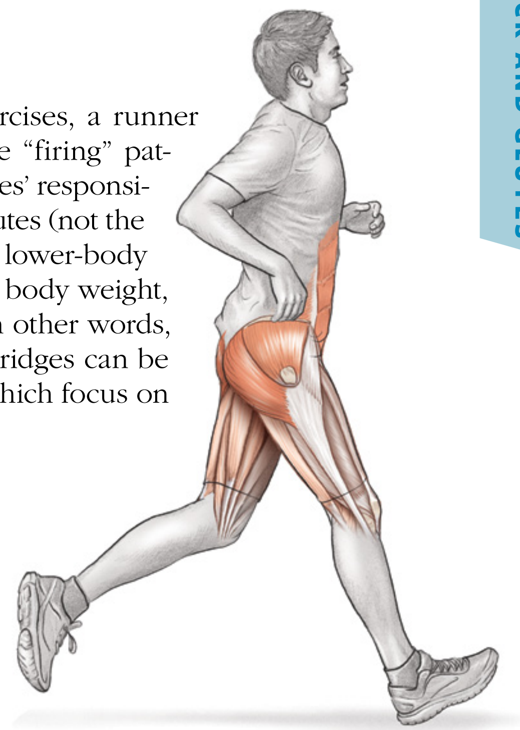
Execution

1. Lie supine (on your back) with both knees bent.
2. Lift your hips into the air as high as you can, simultaneously squeezing your glutes and keeping your scapulae on the floor.
3. Once you are in the bridge position, extend one lower leg straight out and hold for 5 seconds.
4. Lower the leg, then kick and hold with the opposite leg.

Muscles Involved

Primary: Gluteus maximus, gluteus medius, gluteus minimus, rectus abdominis, transversus abdominis

Secondary: Hamstrings (semitendinosus, semimembranosus, biceps femoris)



RUNNING FOCUS

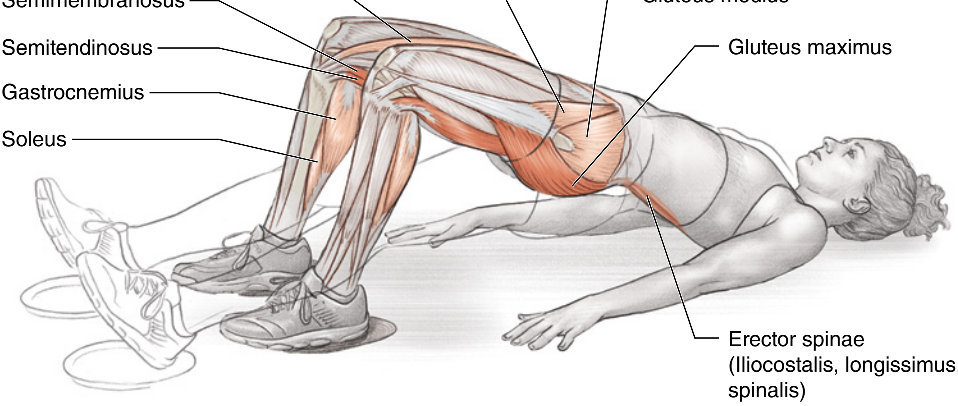
As mentioned in the introduction to these exercises, a runner who has weak glutes—or a problem with glute "firing" patterns—requires other muscles to assume the glutes' responsibilities. Ideally, even for distance runners, the glutes (not the quadriceps) should serve as the powerhouse of lower-body strength. However, since this exercise uses only body weight, it primarily develops the firing of the muscle. In other words, strength development is secondary; therefore, bridges can be complemented by squat exercises (chapter 5), which focus on developing strength.

VARIATION

Weighted Bridge With Leg Kick

Assume the bridge position with the legs bent and a dumbbell resting on the front of each upper thigh (anterior hip). Perform the exercise in the usual manner with the dumbbells increasing the resistance.

SLIDING LEG CURL



SAFETY TIP Keep the shoulders and the head on the floor.

Execution

1. Lie supine on a smooth floor with the knees steepled. Place the feet slightly closer than shoulder-width apart with each foot resting on a plastic gliding disc.
2. Bridge up as high as you can into a single plane from neck to knees.
3. Extend the legs fully by sliding the feet along the floor on the discs, thus lowering the body to prone position.
4. Immediately upon full extension, pull the feet on the gliding discs back while raising the hips back to the original bridge position.

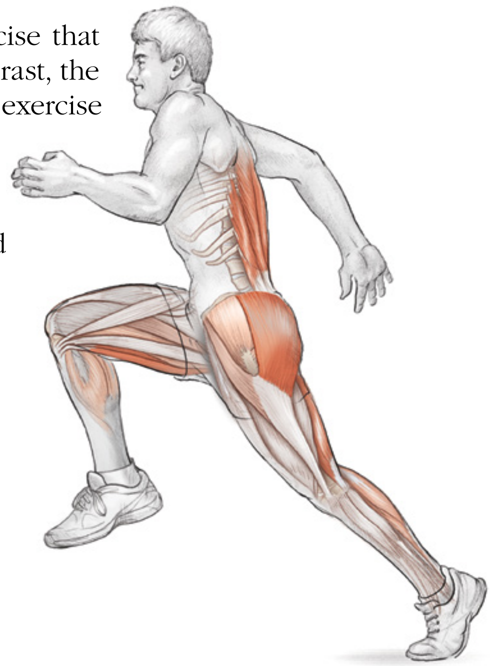
Muscles Involved

Primary: Hamstrings (semitendinosus, semimembranosus, biceps femoris), gluteus maximus, erector spinae (iliocostalis, longissimus, spinalis)

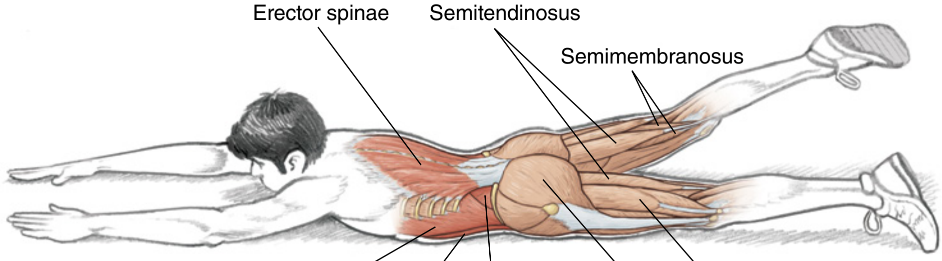
Secondary: Adductor longus, adductor magnus, gluteus medius, gluteus minimus, tensor fasciae latae, sartorius, piriformis, soleus, gastrocnemius

RUNNING FOCUS

The sliding leg curl is a posterior chain exercise that emphasizes both knee and hip flexion (in contrast, the hamstring curl works only knee flexion). This exercise is preferable to other, less functional hamstring exercises because it also requires core stabilization. The ultimate position attained is full extension, which mimics the body position used while running.



LUMBAR HYPEREXTENSION WITH ALTERNATING ARM AND LEG RAISES



TECHNIQUE TIPS

- This exercise can also be performed on a Roman chair, in which case gravity plays a greater role in increasing resistance. Of course, Roman chairs are rarely around when you need them, and performing this exercise on the floor works as well.
- All of the movement should be generated by the glutes and the muscles of the lower back.

Execution

1. Lie prone on the floor with the arms and legs outstretched; keep the body rigid and in a straight line.
2. Raise the left arm and the right leg 3 to 4 inches (8 to 10 cm) off the floor; hold this position for 10 to 15 seconds, breathing throughout.
3. Simultaneously lower the left arm and right leg and raise the right arm and left leg.

Muscles Involved

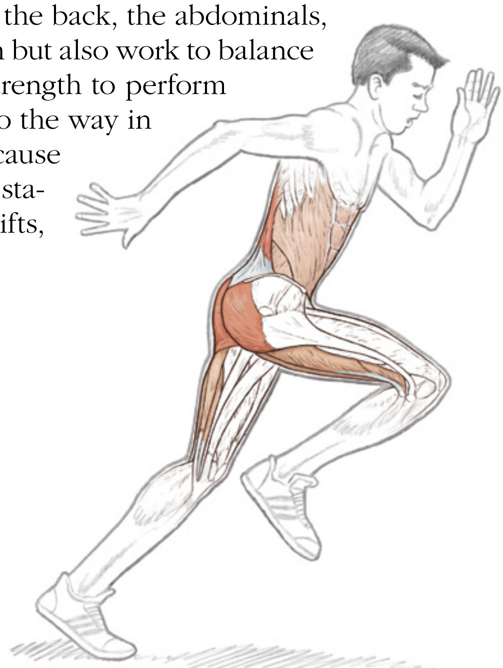
Primary: Erector spinae (iliocostalis, longissimus, spinalis), gluteus maximus

Secondary: Hamstrings (semitendinosus, semimembranosus, biceps femoris), rectus abdominis, external oblique, internal oblique

SAFETY TIP Performing this exercise requires hyperextension of the back. Typically, this is not a problem, but for runners with chronic back pain or disc issues, press-ups are safer.

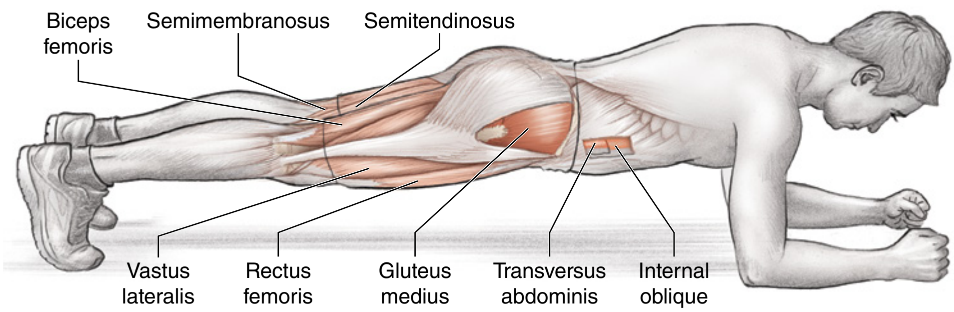
RUNNING FOCUS

Lumbar hyperextensions can be performed in many ways, but the goal remains the same: to both strengthen and stretch the muscles of the lower back, the glutes, and, to a lesser extent, the abdominals in order to help provide the appropriate pelvic tilt during the running gait cycle. A misaligned pelvis causes a chain reaction of misalignment that results in poor running form and wasted energy. To avoid this pitfall, the muscles of the back, the abdominals, and the glutes must not only work in unison but also work to balance each other while still generating enough strength to perform the exercise. This dynamic is very similar to the way in which the core works during running. Because the pelvis rotates and twists, the core must stabilize dynamically by reacting to terrain shifts, turns, and missteps.



PLANK

TECHNIQUE TIP
Don't arch your back, drop your hips, or raise or drop your chin.



Execution

1. Begin in a push-up position.
2. Lower your upper body until your weight is resting on your elbows and your forearms, not on your hands.
3. Your body should form a single plane from shoulders to ankles.
4. Engage your core by contracting your abdominal muscles, pulling your belly button into your spine.

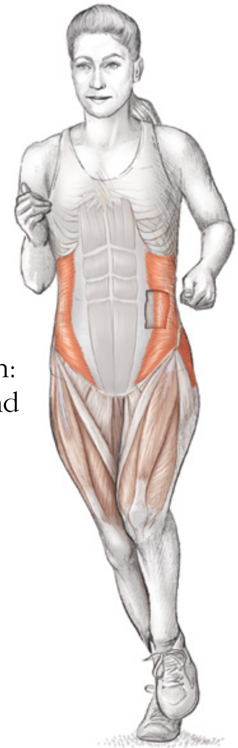
Muscles Involved

Primary: Transversus abdominis, gluteus medius, gluteus minimus, internal oblique

Secondary: Quadriceps (rectus femoris, vastus lateralis, vastus medialis, vastus intermedius), hamstrings (semitendinosus, semimembranosus, biceps femoris)

RUNNING FOCUS

The plank is an isometric exercise, meaning that it involves no change in muscle length or joint angle. Instead, strength is gained by simply holding the muscular contraction; more specifically, the core muscles maintain the single-plane position from shoulders to ankles. Core strength has been touted endlessly for runners, and for good reason—its importance cannot be overstated. The ultimate goal in performing the plank is to hold the body, despite fatigue, in its appropriate position: slightly forward from the ankles, not hinged at the waist, and with the torso like a cylinder.

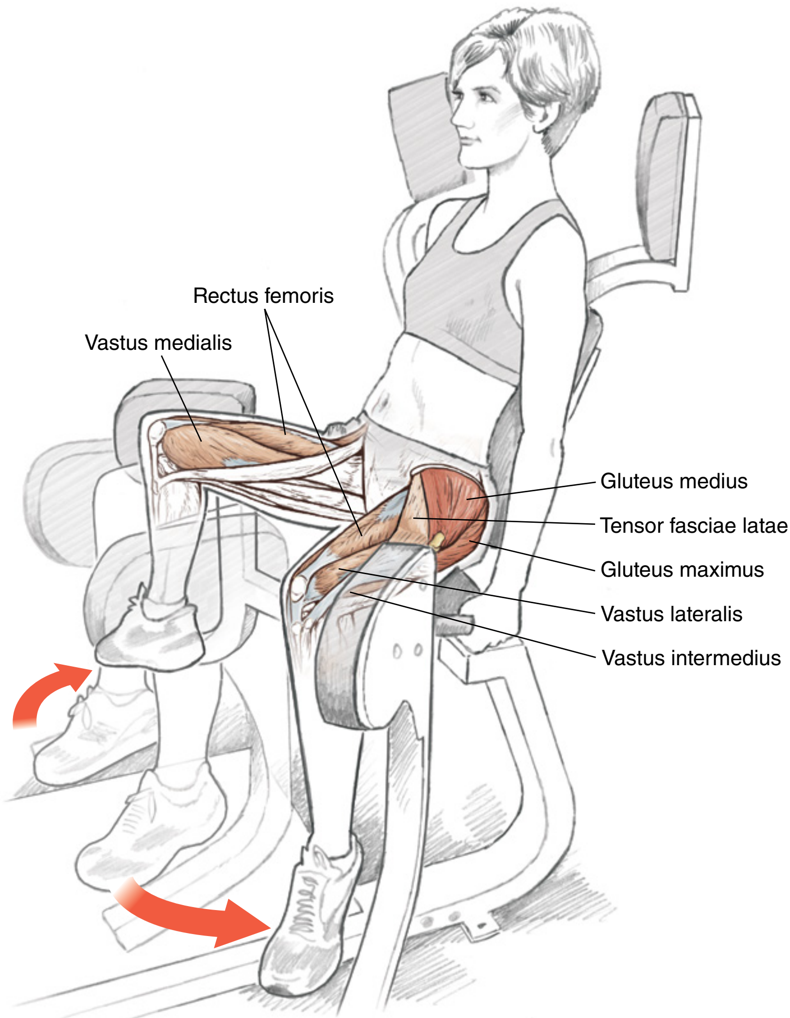


VARIATION

Single-Leg Plank

The single-leg plank begins as a traditional plank. Once the plank position is achieved, gradually raise one leg to the same plane as the glutes, back, and head. Hold for 15 to 30 seconds. Lower the raised leg, then repeat with the opposite leg. This variation can put a lot of pressure on the toes of the foot that remains in contact with the floor. To find the optimal plane, use your core to adjust your body position.

MACHINE HIP ABDUCTOR



TECHNIQUE TIPS

- The motion should be fluid with consistent effort exerted throughout.
- The more upright the backrest, the more emphasis is placed on the gluteus medius.
- Avoid trying to overextend. Do not force the legs higher laterally than your hip naturally allows. Focus on pressing the legs apart using only the targeted muscles of the gluteus.

Execution

1. Assume a proper seated position with the machine pads on the outsides of the knees.
2. Press outward using the abductor muscles (the outsides of the legs); emphasize using a full range of motion.
3. Return gradually to the original position by resisting the weight.

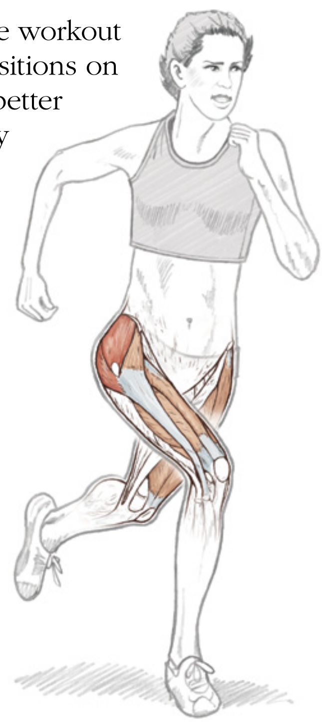
Muscles Involved

Primary: Gluteus medius, gluteus maximus

Secondary: Tensor fasciae latae, quadriceps (rectus femoris, vastus lateralis, vastus medialis, vastus intermedius)

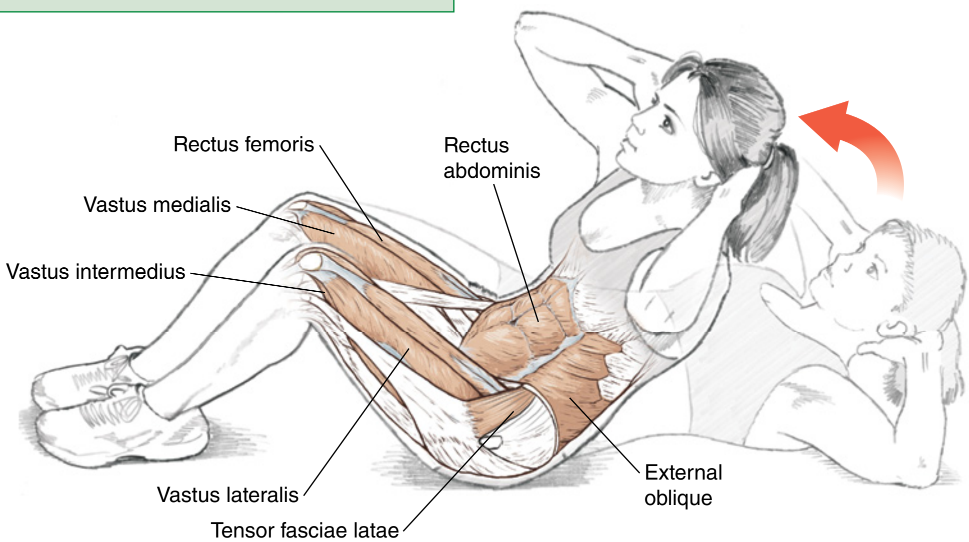
RUNNING FOCUS

The abductor exercise can be performed during the same workout as the adductor exercise. It is easy to change the pad positions on the machine, but its emphasis on the glutes makes it a better fit with the exercises for the glutes and lower back. Many runners, especially those who underpronate, complain of piriformis pain at some point in their running careers. Because of the location of the piriformis muscle, it is difficult to stretch, but abduction exercises help prevent and treat piriformis pain and sciatica by stretching and strengthening the gluteus medius, which is connected.



FLOOR SIT-UP

TECHNIQUE TIP
Sit-ups can be performed with a partner holding down the feet. This approach makes the exercise easier and allows more repetitions to be performed.



Execution

1. Lie supine with the knees steepled, the feet pressed to the floor, and the hands gently touching the back of the head but not clasped.
2. Raise the torso by rounding the back one vertebra at a time while pressing the pelvis down to the floor. Raise the torso only 45 degrees before lowering the back to the floor.
3. Inhale and gradually lower the torso to the floor one vertebra at a time.

Muscles Involved

Primary: Iliopsoas

Secondary: Rectus abdominis, quadriceps (rectus femoris, vastus lateralis, vastus medialis, vastus intermedius), tensor fasciae latae

SAFETY TIP Do not clasp the hands behind the head, which makes it easy to pull the head and torso up by using the muscles of the arms. Instead, just gently touch the back of the head with the hands.

RUNNING FOCUS

Because the quadriceps and hamstrings counterbalance each other, so do the muscles of the abdominals and the lower back. To avoid muscle imbalances and potential injury, perform abdominal exercises *after* performing the strength training exercises for the lower back described in the first part of this chapter. In addition, the sit-up should not be performed for speed but should be done in a relatively quick, fluid manner. The lowering of the torso, in contrast, should be done slowly, with attention paid to the work done by the abdominals.

The dominant muscle affected by sit-ups is the iliopsoas, which connects the leg and the lower back (that is, the bottom and the top of your body). In contrast, the crunch, which does *not* involve lifting the lower back from the floor, targets only the abdominal muscles—a plus for runners who have lower-back pain that can be exacerbated by performing sit-ups. Most back experts prefer the crunch as an abdominal exercise because it does not engage the iliopsoas, rectus abdominis, and tensor fasciae latae, muscles that are often used in running.

Proper movement of the pelvis is critical to the gait cycle. Pelvic misalignment, which may result from imbalance between the abdominal muscles and the lower-back muscles, can cause injuries that impede running performance despite good cardiothoracic fitness.

VARIATIONS

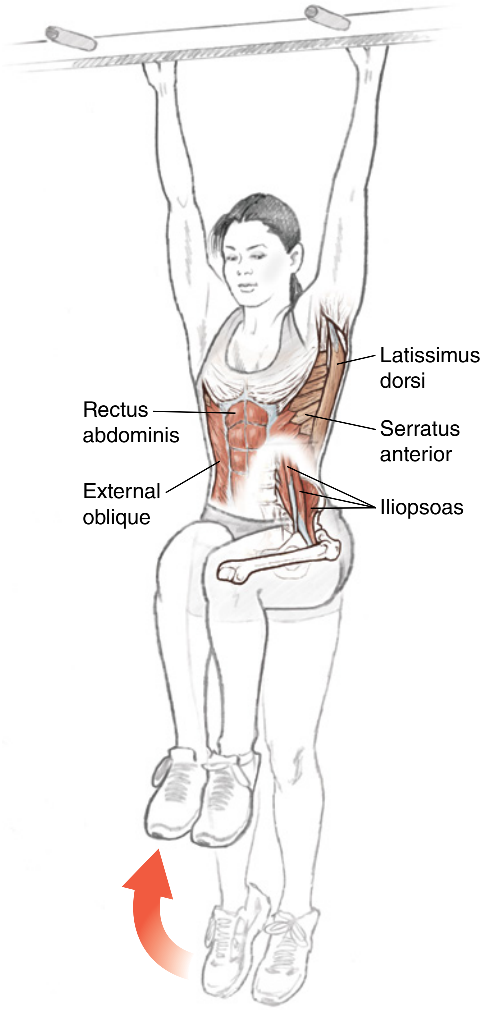
Crunch

Lie supine with the knees steepled and the hands positioned either across the chest or gently behind the head. Initiate movement by curling the shoulders to the pelvis. Keep the lower back on the floor. The key to achieving full benefit from this exercise lies in the articulated curling of the torso while keeping the lower back moored to the floor. The crunch works the rectus abdominis and the obliques.

Oblique Twist

A simple variation on the sit-up and the crunch involves using the oblique muscles to twist the torso by trying to touch an elbow to the opposite hip. You can either alternate sides with each repetition or perform a set of 12 repetitions on one side and then do the other side.

HANGING LEG RAISE



Execution

1. Hang from a pull-up bar with the palms facing forward. Emphasize lengthening and feel gravity exerting its force on the spine.
2. Using a controlled movement, bring the knees up toward the chest; keep the torso from swinging.
3. Gradually return to full extension, then repeat.

Muscles Involved

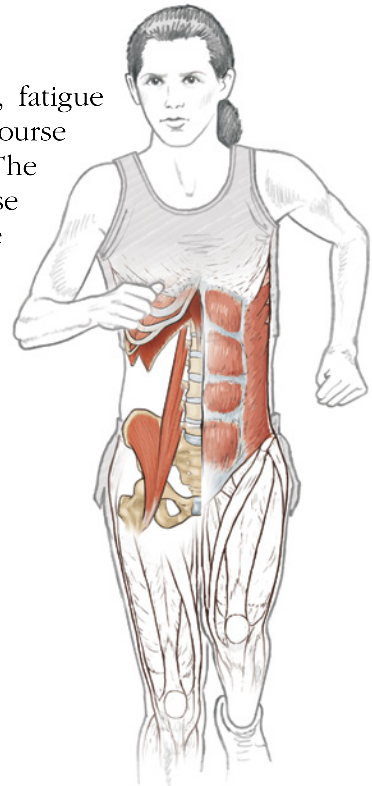
Primary: Rectus abdominis, external oblique, iliopsoas

Secondary: Latissimus dorsi, serratus anterior

SAFETY TIP This exercise can put a lot of stress on the shoulders; therefore, if the shoulders are compromised, limit the number of repetitions performed.

RUNNING FOCUS

The hip flexor muscles, specifically the iliopsoas, fatigue greatly during a long run or during a race on a course characterized by the same terrain throughout. The repetitive nature of running is exacerbated on a course with few terrain changes, and smaller muscles fatigue quickly. Runners can delay the onset of this fatigue by strengthening the iliopsoas and the other hip flexors. When the terrain is hilly, requiring a lot of lifting throughout a run, weaker muscles fatigue more quickly and it is hard to gain solid footing.

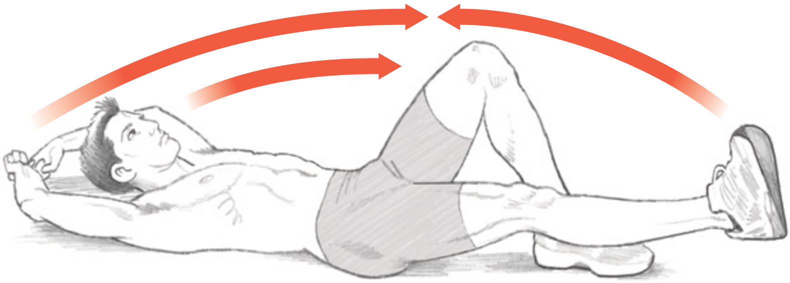


VARIATION

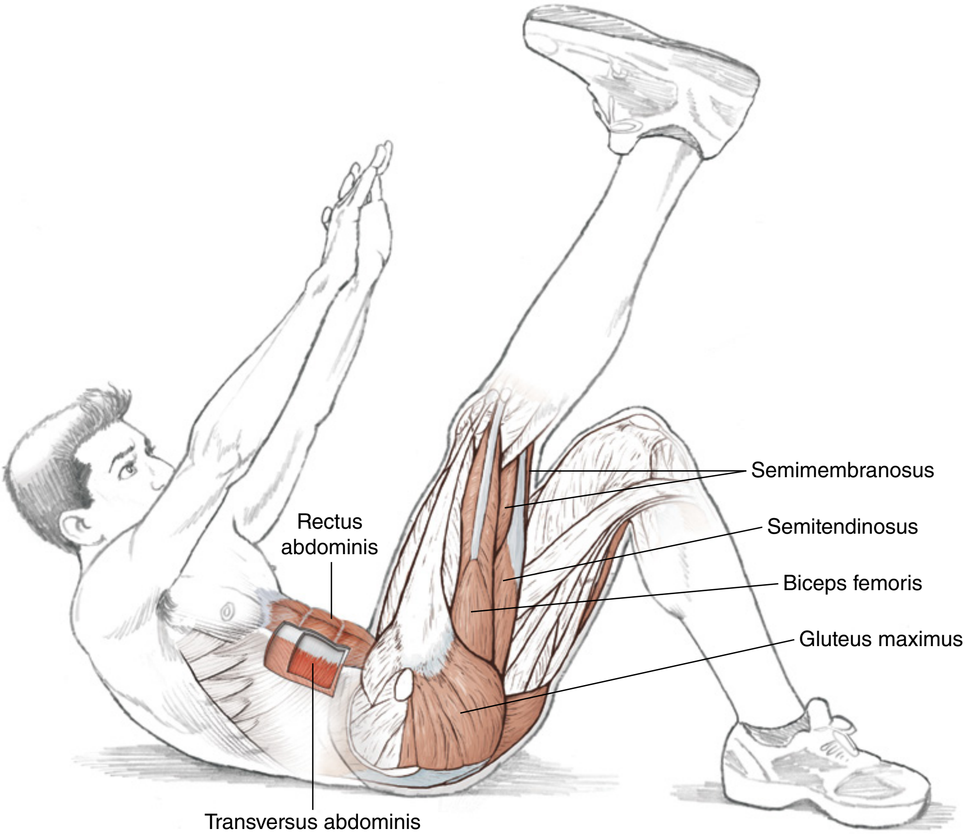
Hanging Leg Raise With Twist

The standard hanging leg raise does affect the external oblique and the internal oblique, but adding a twist to the side increases the role of these abdominal muscles, which are responsible for rotation and lateral flexion of the torso. As mentioned in the introduction to this chapter, the oblique muscles help the body twist, thus allowing for terrain adjustments; they also aid respiration by working in conjunction with the diaphragm and the ribs.

SINGLE-LEG V-UP



Start position.



Execution

1. Lie flat on your back with your hands reaching back behind your head. One leg is steepled, and the other is raised approximately 6 inches (15 cm) off the floor.
2. Leading with the chin and chest, engage the abdominals to rise as in a sit-up, while also raising the leg that is off the floor so that it meets the hand at its apex.
3. Recline to the initial position. Repeat, reaching for the other leg.

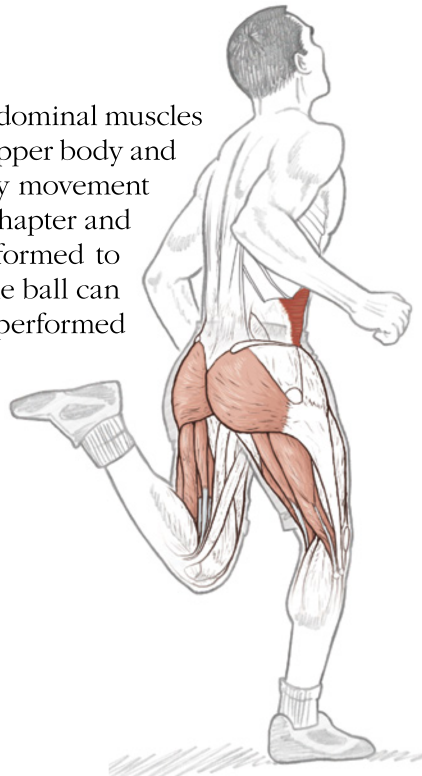
Muscles Involved

Primary: Rectus abdominis, transversus abdominis, iliopsoas

Secondary: Hamstrings (semitendinosus, semimembranosus, biceps femoris), gluteus maximus

RUNNING FOCUS

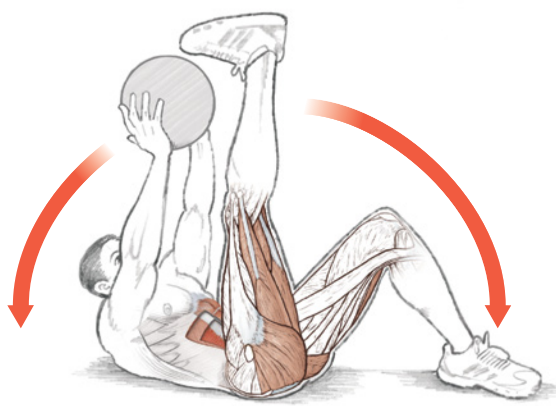
This exercise is dynamic and quickly fatigues the abdominal muscles and the iliopsoas. Because it incorporates both the upper body and the lower body, it constitutes more of a whole-body movement than some of the other exercises presented in this chapter and more closely resembles a running movement. Performed to failure, this exercise and its variation with a medicine ball can serve as an entire abdominal workout, especially if performed as the final exercise in a strength training session.



VARIATION

Single-Leg V-Up With Medicine Ball

The addition of the medicine ball works the abdominals harder because of the added weight. Even a 5-pound (2 kg) ball feels heavy because the ball is held away from the abdominals, which serve as the fulcrum. In addition, the challenge of coordinating the movement with the added weight helps develop coordination—a skill not developed by simply running in a forward motion.



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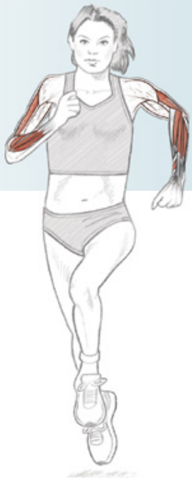


7

SHOULDERS AND ARMS

Sir Murray Halberg, a New Zealander, won the Olympic 5,000-meter run with a withered arm that resulted from an earlier sporting accident. Thus, even people who lack arms are perfectly capable of running, and they often do so very well. At the same time, the arms typically play an important role in a smooth running motion. Specifically, each arm not only contributes to the runner's balance but also aids in forward movement by acting as a counterbalance as the opposite leg drives away from the ground. To appreciate this dynamic, try leading with your right hand and right leg at the same time. At best, it will feel unnatural; at worst, you will fall over! For another illustration, watch a sprinter come out of the blocks—a high knee lift accompanies exaggerated opposite-arm action for the first dozen strides, after which the arms continue to pump away for the remainder of the sprint.

Distance runners, on the other hand, would waste precious energy by driving the arms in this fashion, because their running prioritizes economy of effort. Instead, their arms hang fairly loosely, usually with the elbows bent at about 90 degrees and the hands relaxed beyond the wrist joints. Sprinters' fingers, in contrast, are held straight and tense as the runner drives each stride. Thus arms play a serious role in successful running, though in distinctly different ways depending on the type of run being attempted.

The points at which the arms are attached to the body—the shoulder joints—take the form of a shallow ball and socket that permits maximum movement through as close to 360 degrees as possible. This structure is quite effective, although the easy mobility comes at the price of an unstable joint that can be easily damaged. More specifically, to allow easy movement, the ligaments that hold the bony shoulder components in place must be relatively elastic; therefore, the stability of the joint relies on the strength of the retaining muscles.

Here it may be helpful to recall Newton's third law of motion: For every action, there is an equal and opposite reaction. In this case, if a muscle contracts and pulls the shoulder in one direction, then one or more other muscles must lengthen in order to allow that to happen.

Another key factor is muscle balance. Generally, strong muscles with good tone tend to separate a joint if the opposing muscles are weak and undeveloped. This is never truer than with the shoulder joint.

The ball of the shoulder joint, at the upper end of the humerus, is located in the shallow glenoid labrum, or cavity, which is itself a part of the winged scapula that surrounds the posterior portion of the upper thorax. From the runner's point of view, it is beneficial to know the muscles that maintain the position of the humeral head (figure 7.1) and which ones can be strengthened to improve running motion.

When the legs take large strides, their movement requires a similarly large backward and forward movement of the arms to balance the leg action. In addition, especially in sprinting, the arms and shoulders play a large role in propulsion. A sprinter who is losing a race often tenses the shoulders while fading back though the field. Tired arms and tense shoulders lead to a less fluent arm swing and a shorter stride, which consume precious energy. Thus the endurance provided by strength training of the upper limbs can make the split-second difference between success and a lifetime of disappointment. For these reasons, the exercises presented here are just as important as those that address the lower limbs.

The outermost layer is formed by the triangular deltoid muscle (figure 7.2). It arises from the clavicle (collarbone) and part of the top of the scapula to cover the whole joint. It is inserted into the middle of the humerus, where its con-

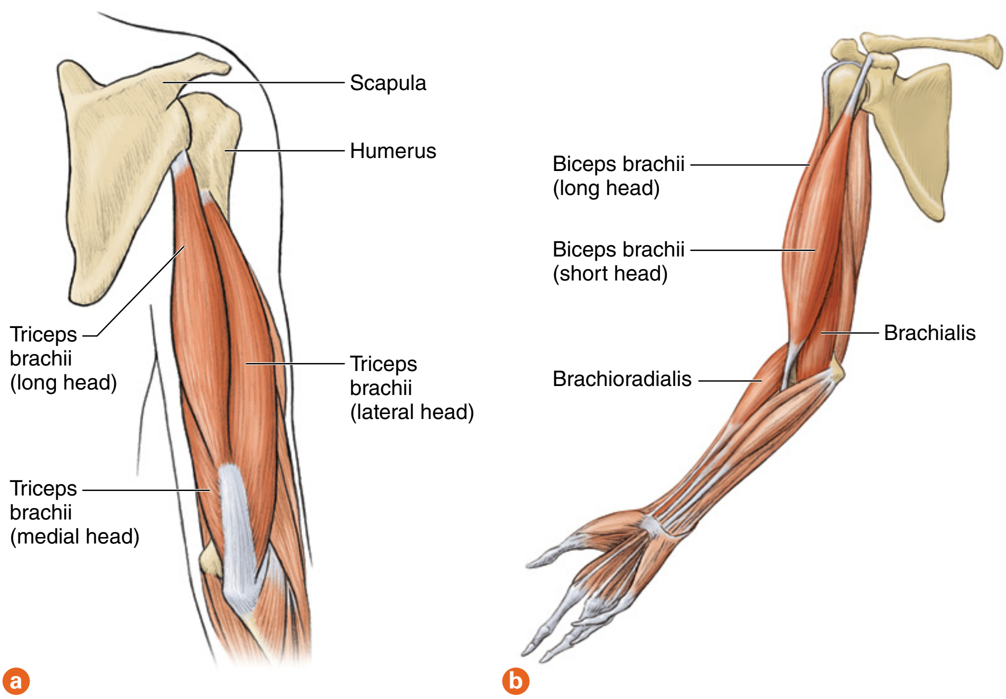


FIGURE 7.1 Upper arm: *(a)* back and *(b)* front.

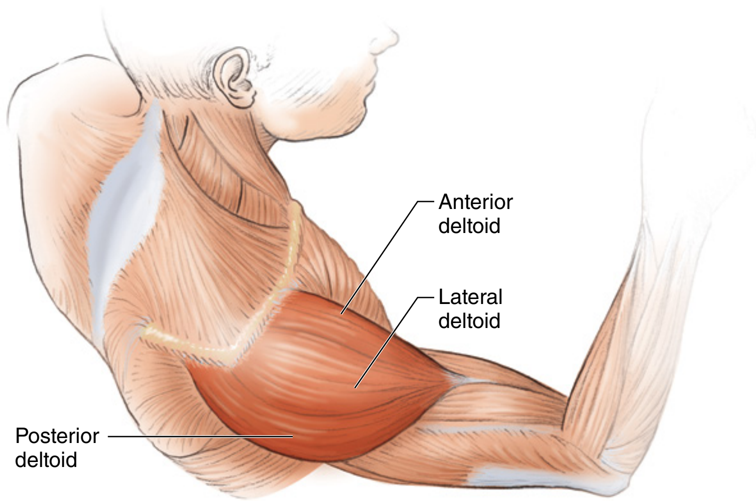


FIGURE 7.2 The deltoid.

tractions pull the arm out sideways into abduction; thus it opposes gravity. The complicated arrangement of muscles underneath the deltoid has developed to enable movement in most planes. This capacity matters little to runners, whose arms need to move no more than 45 degrees fore and aft, with minimal sideways movement. As a result, these muscles need to be strong rather than elastic.

A complex web holds the arm to the shoulder. In particular, the supraspinatus braces the head of the humerus, whereas the infraspinatus, subscapularis, teres major, and teres minor (figure 7.3) both connect together and stabilize the shoulder.

Below the shoulder are located the biceps brachii, triceps brachii, and brachialis muscles. Their primary function is to move the elbow joint, but some fibers are attached around the shoulder, thus enhancing its stability.

Continuing down the arm, the extensor and flexor muscles of the forearm (figure 7.4) rotate the wrist inward and outward and also move the wrist and fingers. The flexors bend these joints in, and the extensors open them out. Runners do not need detailed knowledge of these parts of the anatomy, but they do need strength and flexibility in these areas. Specifically, exercises that promote these qualities are important for increasing one's running speed.

Once again, any weakness slows the runner, which means that, particularly for power sprints, the arms must have endurance equal to that of the legs. This need explains why the physique of a sprinter's upper limbs is not unlike that of a boxer. Evolution has led us to use the arms when running, first to help stabilize the body and then to keep it upright as each leg moves. For an illustration, study a steeplechase runner in slow-motion replay and notice that the arms help the body prepare for each takeoff, flight, and landing. Strong upper limbs not only aid in the production of full power when sprinting but also help the shoulders

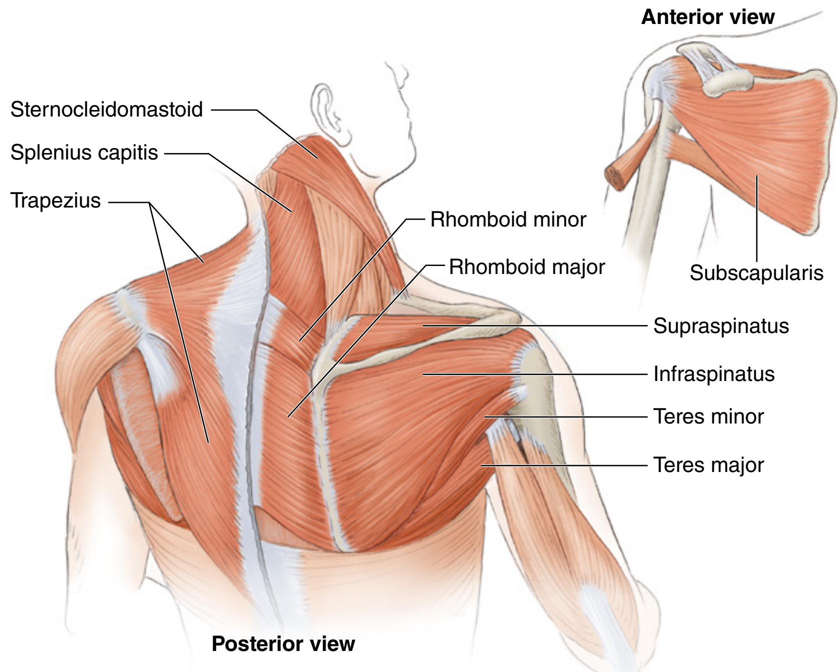


FIGURE 7.3 Muscles of the scapula and rotator cuff.

relax; when the shoulders tense, the runner inevitably slows. In short, a sprinter without arm movement will find it very difficult to achieve real speed!

Finally, the legs are unable to run with full efficiency if the arms are not involved in the running action. When the arms fatigue, both stride length and stride rate diminish, and the runner slows down. As a result, a runner with strong legs who wants to speed up toward the end of a run will be hindered by upper limbs that have not been trained for the task.

SPECIFIC TRAINING GUIDELINES

Any exercise that uses the arms will strengthen them; even the simple act of holding a weight while performing an exercise is a form of isometric strength training. Most runners, if they do specific arm exercises at all, emphasize the biceps. Here, therefore, we emphasize the triceps in order to help balance the muscular strength of the arms. Both biceps and triceps exercises can be performed with relatively small amounts of resistance. Since distance runners need to be able to swing their arms steadily in the later stages of a long run or race, rather

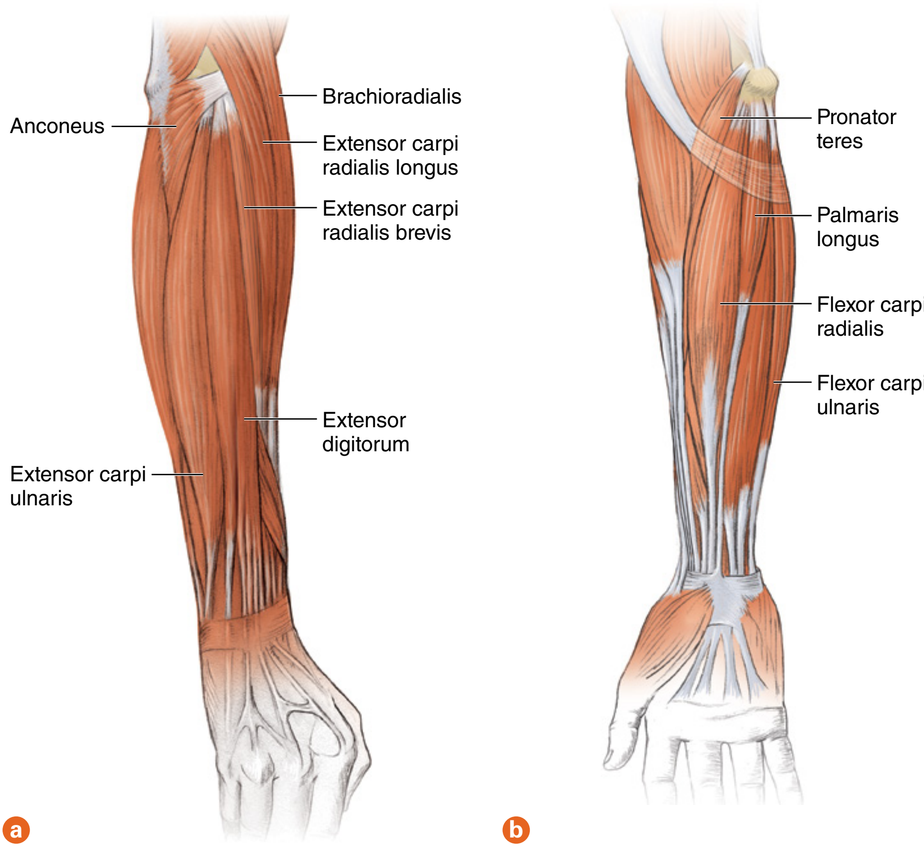


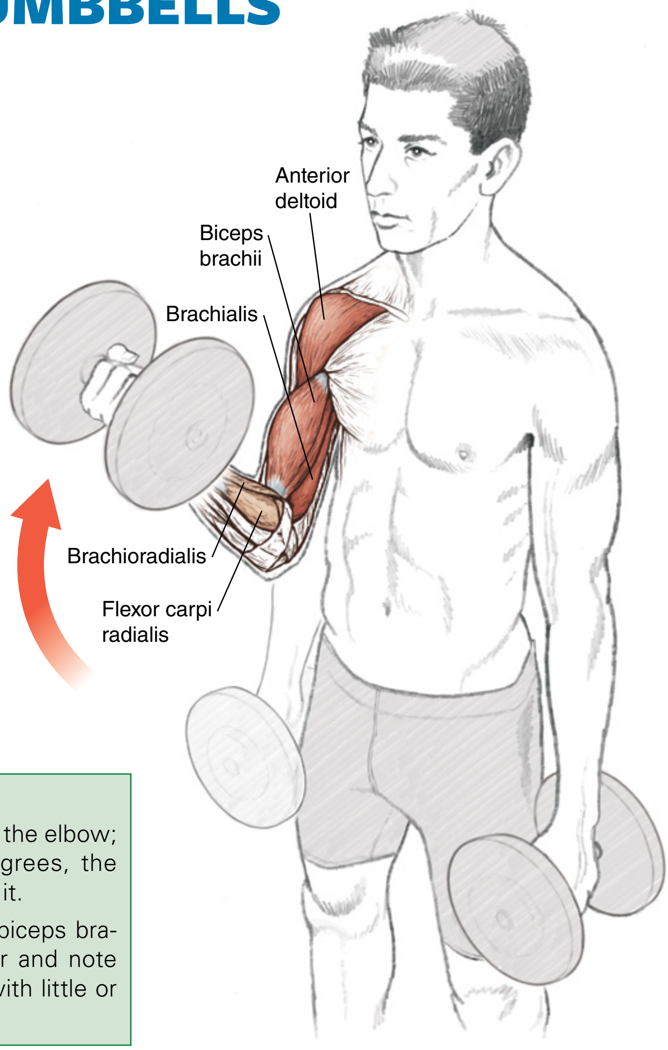
FIGURE 7.4 Forearm: *(a)* front and *(b)* back.

than use their arms to help produce sudden power, distance runners' emphasis on training their arms should be placed on doing a relatively large number of repetitions (18 to 24) in order to promote muscular endurance. In contrast, for sprinters and middle-distance runners, 4 to 6 repetitions of a heavier weight will suffice to build strength.

When performing biceps exercises, keep your back straight; do not rock to help lift the weight. Choose a weight that does not hinder the smooth motion of the curl, and choose a lighter weight rather than a heavier one to start with. Also, keep your elbows fixed and close to your body in order to emphasize the biceps and not the shoulders.

Here is a good order for a sample arm workout: narrow-grip barbell curl, double-arm dumbbell kickback, and reverse wrist curl.

ALTERNATING STANDING BICEPS CURL WITH DUMBBELLS



TECHNIQUE TIPS

- The upper arm should be fixed at the elbow; as the dumbbell passes 90 degrees, the upper arm should not move with it.
- To help you focus on using the biceps brachii, look sideways into a mirror and note whether the elbow stays fixed with little or no swaying.

Execution

1. Stand with the feet shoulder-width apart and the knees slightly bent. Hold a dumbbell in each hand with the arms hanging straight down from the shoulders and the palms facing inward.
2. In one smooth motion, curl one dumbbell upward, completing a full range of motion; concentrate on using the biceps rather than the hand.
3. Using a slow, fluid movement, lower the dumbbell and feel the stretch as it returns to its starting position. Repeat the exercise with the other arm.

Muscles Involved

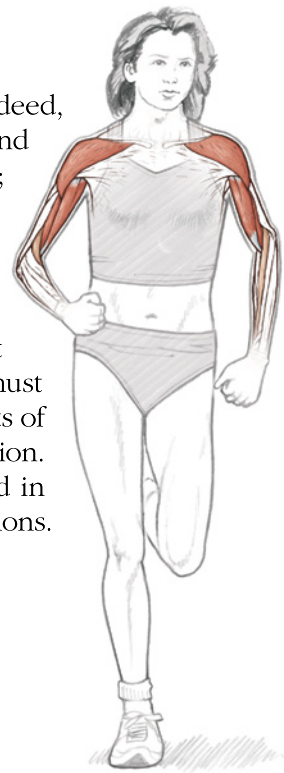
Primary: Biceps brachii, brachialis, anterior deltoid

Secondary: Brachioradialis, flexor carpi radialis

SAFETY TIP This is a simple exercise that can go awry if too much weight is used. The ideal weight is heavy enough to provide resistance throughout each repetition and set, but not so heavy that poor form eventually results. To maintain proper form, do not throw the weight by engaging your upper-back muscles; the movement should be dominated by the biceps.

RUNNING FOCUS

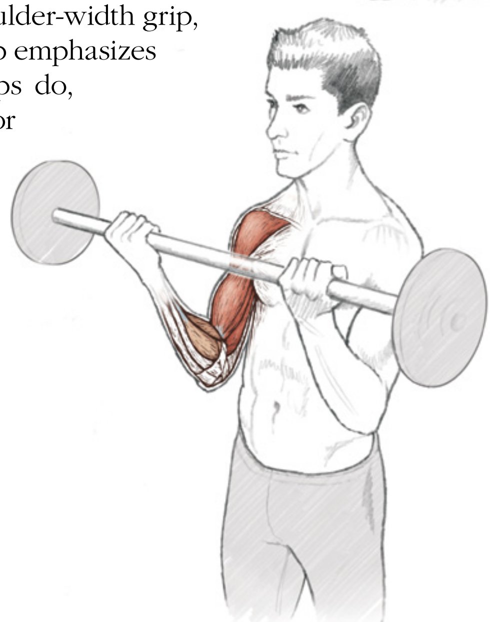
It may seem odd that runners need to develop biceps strength. Indeed, most distance runners appear emaciated due to their thin arms and legs. This does not, however, mean that their biceps are weak; developing strength is different from adding mass. When the biceps exercise is performed with enough resistance to stimulate strength gains—and when it is done with a relatively high number of repetitions in conjunction with a strenuous running program—it promotes functional strength endurance without adding mass. This is crucial for distance runners, whose arms must balance them from side to side and counterbalance the movements of the legs without fatiguing during a grueling training or racing session. Thus strength endurance is paramount, and it can be developed in part by performing this exercise for multiple sets of 12 to 18 repetitions.



VARIATION

Barbell Curl With Variable-Width Grip

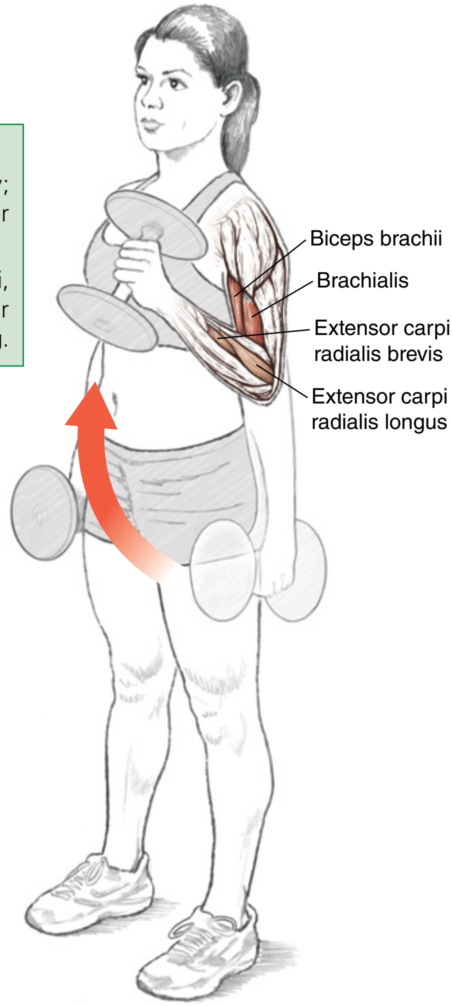
Barbell curls can be done with a normal shoulder-width grip, a narrow grip, or a wide grip. The narrow grip emphasizes the biceps brachii more than the other grips do, whereas the wide grip incorporates the anterior deltoid (the large muscle encapsulating the shoulder). All three grips are appropriate, and a complete biceps workout can be created by using just this one exercise with one set devoted to each grip.



ALTERNATING STANDING HAMMER CURL WITH DUMBBELLS

TECHNIQUE TIPS

- The upper arm should be fixed at the elbow; as the dumbbell passes 90 degrees, the upper arm should not move with it.
- To help you focus on using the biceps brachii, look sideways into a mirror and note whether the elbow stays fixed with little or no swaying.



Execution

1. Stand with the feet shoulder-width apart. Hold a dumbbell in each hand with the arms hanging straight down from the shoulders and the palms facing inward.
2. In one smooth motion, curl one dumbbell upward until it touches the shoulder, completing a full range of motion. Concentrate on using the biceps, not the hand. The upper arm should be fixed at the elbow; as the dumbbell passes 90 degrees, the upper arm should not move with it.
3. Using a slow, fluid movement, lower the dumbbell and feel the stretch as it returns to its starting position. Repeat the exercise with the other arm.

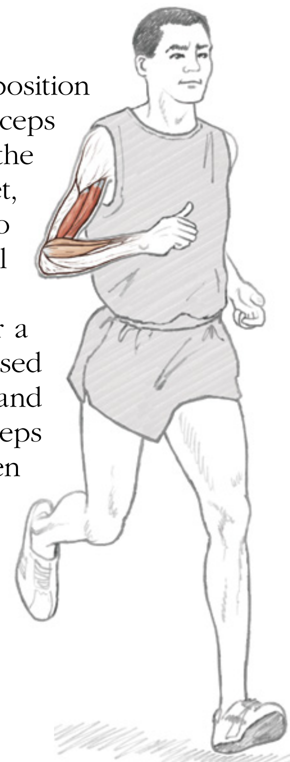
Muscles Involved

Primary: Biceps brachii, brachialis

Secondary: Triceps brachii, extensor carpi radialis brevis, extensor carpi radialis longus

SAFETY TIP Avoid throwing the weight; focus on contracting the biceps.

RUNNING FOCUS



Similar in execution to the biceps curl—only the hand position is changed—the hammer curl develops strength in the biceps and, to a lesser extent, the brachialis. Performed during the same strength training session at the end of the biceps set, the hammer curl is a fatigue-inducing exercise that also promotes joint flexibility because of its resistance over a full range of motion.

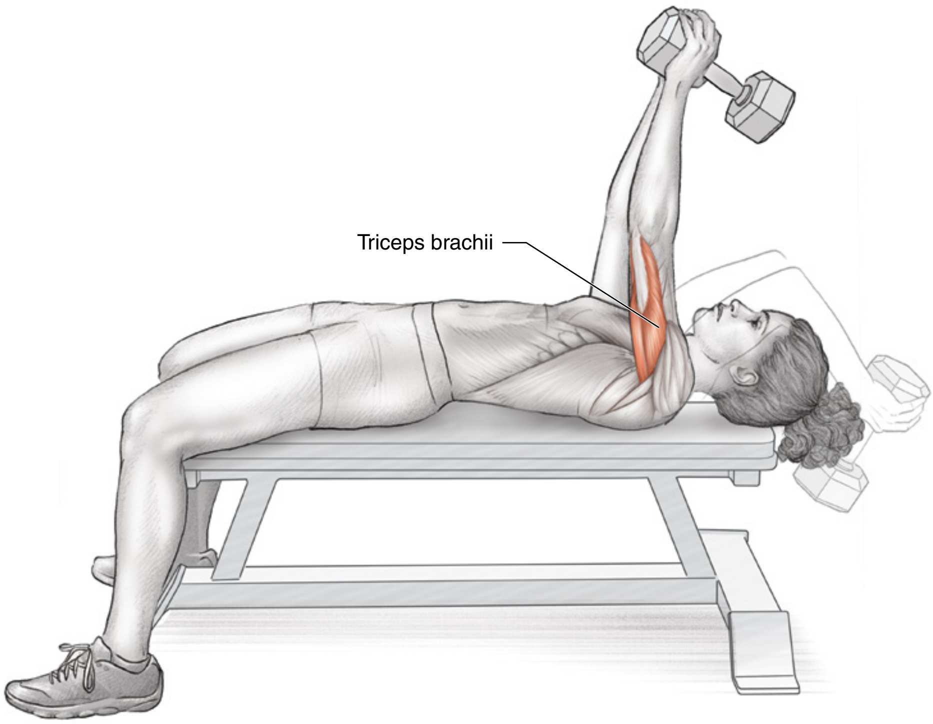
Runners often complain of sore biceps during and after a race of relatively short duration and intense effort. The increased force of the arm carriage in such races places greater demand on the muscles of the upper arm. By performing the biceps exercises, runners can stave off this kind of fatigue and shorten their recovery time between repetitions and sets during a track workout.

VARIATION

Seated Double-Arm Hammer Curl

Sit on the edge of a flat bench with the feet flat on the floor, the back erect, and the arms hanging down with a dumbbell in each hand and the palms facing inward. Perform the hammer curl motion with both arms simultaneously. This exercise involves coordinating the movement of both arms and may cause fatigue a bit sooner than when alternating the arms.

DUMBBELL LYING TRICEPS EXTENSION



Execution

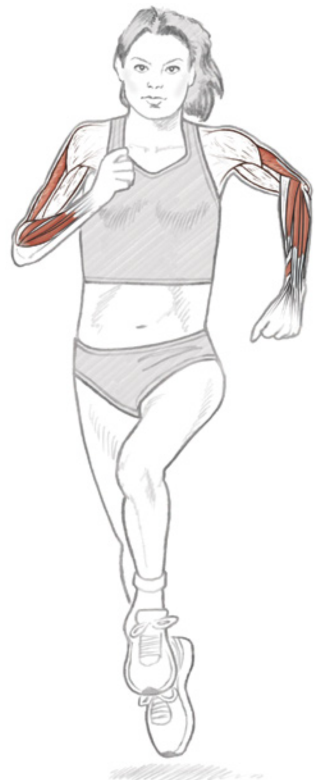
1. Lie on your back on a flat bench with both feet on the floor. The torso should be stable, and the arms are shoulder-width apart and bent 90 degrees at the elbow. Hold a dumbbell of an appropriate weight with both hands and with the palms facing inward.
2. Extend the forearms to full extension.
3. Slowly lower the arms to the initial position by resisting the weight.

Muscles Involved

Primary: Triceps brachii

SAFETY TIP Have a spotter place the weight in your hands and hold it in place until you begin the exercise. If there is no spotter, begin the exercise with the arms in the extended position and perform the negative (lowering) action as the first movement.

RUNNING FOCUS

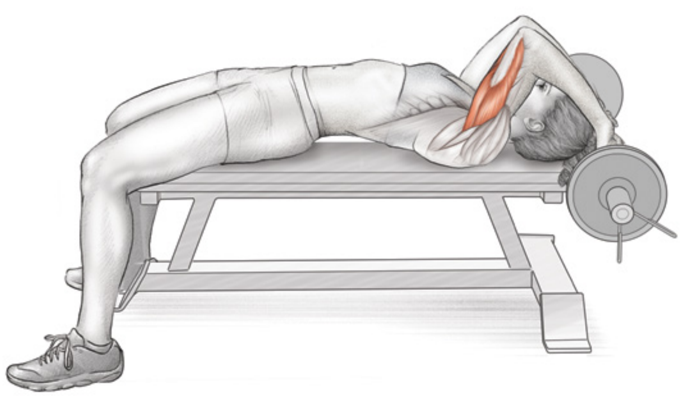


The introduction to this chapter emphasized the importance of the arms in balancing and counterbalancing the body during running. With that need in mind, the triceps exercises presented in this section balance the recommended biceps exercises, thus creating a well-developed and strengthened upper arm. The muscles of the forearm are involved here as secondary movers. Movement occurs in these exercises only at the elbow joint and is precipitated by engaging the triceps.

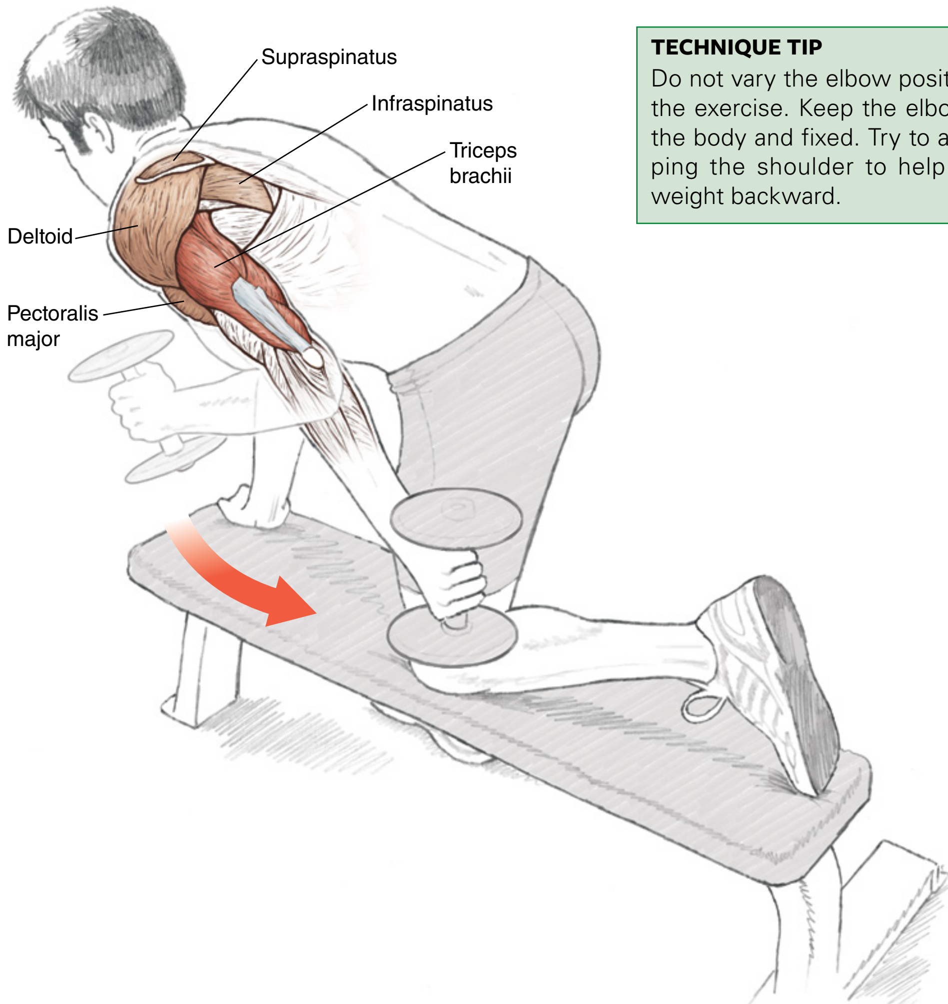
VARIATION

Barbell Lying Triceps Extension

Instead of using a dumbbell, use a barbell while otherwise executing the exercise in the same way as with the dumbbell. Follow the same safety instructions.



SINGLE-ARM DUMBBELL KICKBACK WITH BENCH



TECHNIQUE TIP
Do not vary the elbow position during the exercise. Keep the elbow tight to the body and fixed. Try to avoid dropping the shoulder to help push the weight backward.

Execution

1. Kneel on a flat bench with one leg. Keep the spine and torso in a straight line with your head. Establish a stable base of support with the non-weight-bearing hand pressed to the bench and the opposite-side leg extended with the foot on the floor. The weight-bearing arm is bent at about a 90-degree angle with the palm inward.
2. Extend the forearm backward from the elbow, using the triceps muscles to instigate the movement slowly and fluidly. Keep the elbow in a fixed position parallel to the torso—not higher. Exhale during this motion.
3. Upon straightening the arm, allow the weight to return the arm to 90 degrees while you provide gentle resistance. Inhale during the return.

Muscles Involved

Primary: Triceps brachii

Secondary: Infraspinatus, supraspinatus, deltoid, pectoralis major

RUNNING FOCUS

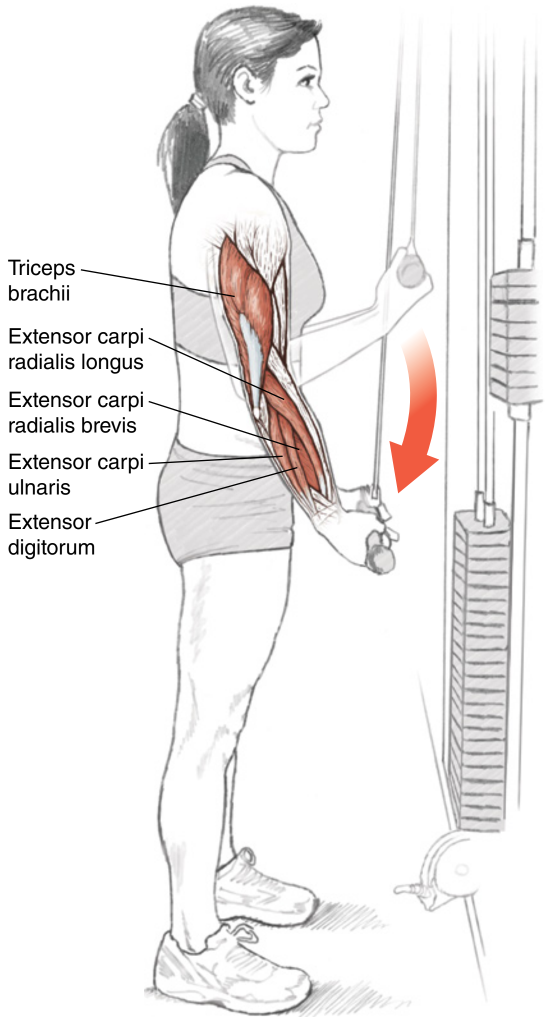
This is primarily a triceps exercise, but it also recruits the infraspinatus and supraspinatus muscles of the shoulder. Because the arm swing is initiated in the shoulder during running, using this exercise to strengthen the triceps and the shoulder helps ward off arm fatigue and bad posture—two energy-sapping scourges of good performance.

VARIATION

Double-Arm Dumbbell Kickback

The double-arm variation does not require a bench. From a standing position with the feet shoulder-width apart, bend over at the waist so that your torso is close to parallel to the floor. Grasp a dumbbell in each hand with the arms hanging downward. Perform the kickback movement with both arms simultaneously. This exercise uses the same muscles as the single-arm kickback with a bench but also incorporates the core muscles of the abdomen and lower back to stabilize the body.

MACHINE REVERSE PUSH-DOWN



Execution

1. Stand with your feet closer than shoulder-width apart. Grasp the short, straight bar attached to a cable (on a pulley attached to the machine) with the palms upward (that is, using an underhand grip). The forearms are extended at about a 75-degree angle from the elbows, which remain fixed at your sides throughout the exercise.
2. In a smooth, uninterrupted motion, push the forearms downward in full extension while keeping the elbows fixed in their original position and close to the body. Exhale throughout the motion.
3. Allow the weight to return gradually and smoothly to the original position as you resist the pull of the cable. Inhale during this part of the exercise.

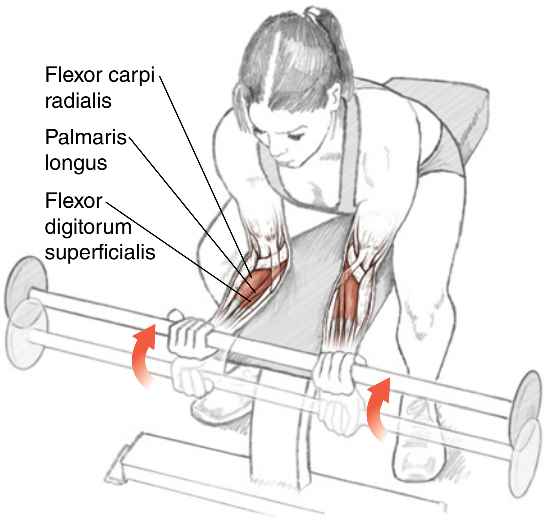
Muscles Involved

Primary: Triceps brachii, extensor carpi radialis longus, extensor carpi radialis brevis, extensor carpi ulnaris, extensor digitorum

RUNNING FOCUS

The reverse push-down mainly works the triceps, but it also works the forearm muscles because of the underhand grip. This exercise makes for a nice transition from the triceps-dominated extension and kickback into the next exercises—wrist curls—which predominantly work the forearm muscles. The triceps muscles and the extensor muscles of the forearm fatigue quickly during this exercise, as they do during a shorter distance race (5K to 10K) when using the arms becomes a means of propelling the legs during a surge or final push.

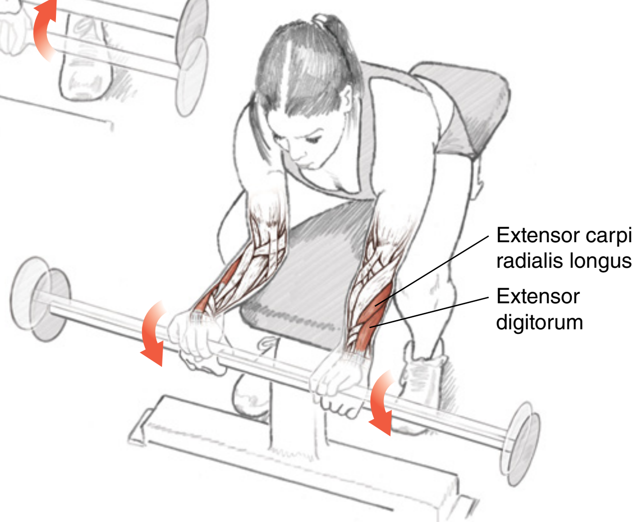
WRIST CURL AND REVERSE WRIST CURL



Wrist curl.

TECHNIQUE TIPS

- Focus on experiencing a full stretch of the muscles but do not allow the barbell to snap down.
- If it is difficult to rest your forearms on the bench, you can rest them on your legs.



Reverse wrist curl.

Execution for Wrist Curl

1. Lean forward with your forearms resting on a flat bench. The wrists and hands should extend beyond the bench, and the palms should face up. A barbell of light weight rests forward of the palms, and the fingers are closed gently around the bar.
2. Raise the barbell by raising your hands while using only the muscles of the forearms and hands; move through a full extension.
3. Return the weight gradually to its original position by resisting the barbell as it moves downward.

Execution for Reverse Wrist Curl

1. Lean forward with your forearms resting on a flat bench. The wrists and hands should extend beyond the bench, and the palms should face downward. A barbell of light weight is gripped securely by the palms and fingers.
2. Raise the barbell by raising your hands while using only the muscles of the forearms and hands; move through a full extension.
3. Return the weight gradually to its original position by resisting the barbell as it moves downward.

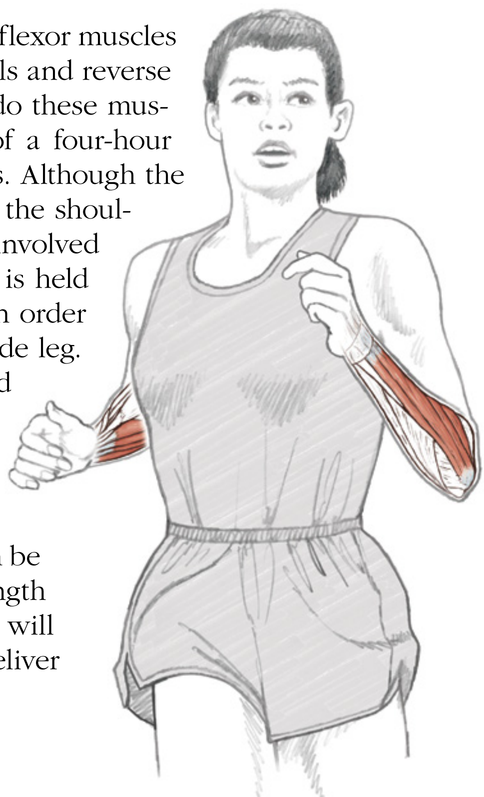
Muscles Involved

Primary: Flexor carpi radialis, palmaris longus, flexor digitorum superficialis, extensor carpi radialis longus, extensor digitorum

RUNNING FOCUS

After gradually incorporating the extensor and flexor muscles into the strength training routine, use wrist curls and reverse wrist curls to emphasize these muscles. How do these muscles factor into running? During the course of a four-hour marathon, each arm swings some 22,000 times. Although the movement is initiated by the larger muscles of the shoulders, the upper arms and forearms are also involved in the arm carriage. Specifically, each forearm is held at about a 90-degree angle to the upper arm in order to counterbalance the action of the opposite-side leg.

During the course of 22,000 arm swings and four hours of being held aloft (fighting gravity), fatigue is bound to set in, thus creating a chain reaction of biomechanical adjustments that result in poor form and wasted energy. This fatigue and the resulting chain reaction can be mitigated, if not eliminated, by performing strength training exercises for the arms. As a result, you will waste less energy and therefore be able to deliver better performances.



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8

CHEST AND BACK

Anyone who understands the function of a bellows (as in an accordion) will soon grasp the anatomy of the thorax, better known as the chest. Bellows (and accordions) have evolved as a way to move air under pressure in order to produce currents of air (and musical sounds). The same is true of the human thorax. The principal bony architecture of the chest (figure 8.1) consists of 12 thoracic vertebrae that are placed one on top of another. They are interlocked by ligaments and other soft tissues in a way that allows movement in the anterior (front) and posterior (rear) directions, limited lateral (side) motion, and a degree of rotation that enables the torso to twist. Emerging from the side of every thoracic vertebra are two bony ribs that arc around and meet at the front; the majority of them form the sternum, or breastbone.

The outside or posterior of the vertebrae is supported by the erector spinae muscles, which run the length of the spine; however, each rib hangs from the rib above, including the "false" ribs, and they are held together by the intercostal muscles in a structure much like that of a venetian blind. Even so, without further structural support, the ribs would be unstable; therefore, the maintenance of the position of the ribs in relation to each other is aided by the trapezius, the latissimus dorsi, the rhomboids, the teres group, the shoulder stabilizers, and the pectoralis major and pectoralis minor (figure 8.2). At the base of this dome, with attachments to the lower ribs, lies the vast diaphragm, which encircles the base of the thorax. Further stability is added by the abdominal muscles, the rectus abdominis, the external oblique, and the serratus anterior.

Running makes far greater demands on the body for oxygen than does sedentary life. To meet these demands, the diaphragm uses a bellows-like action as it contracts to draw air into the lungs. At the same time, the intercostal muscles relax, only to contract strongly with expiration, during which time the diaphragm relaxes and is drawn up into the thorax.

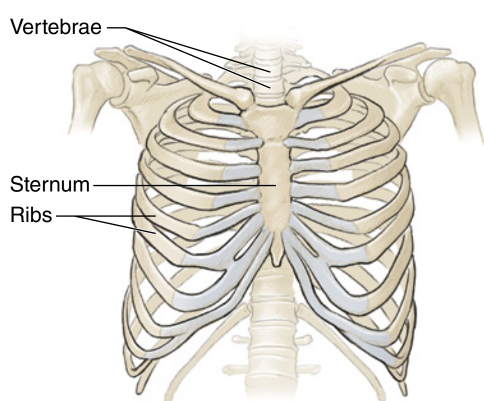
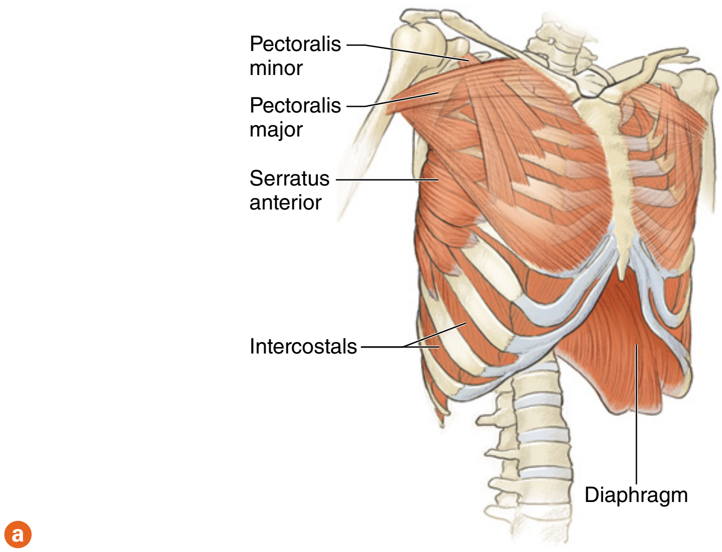


FIGURE 8.1 Bony structures of the torso: ribs, sternum, and vertebrae.



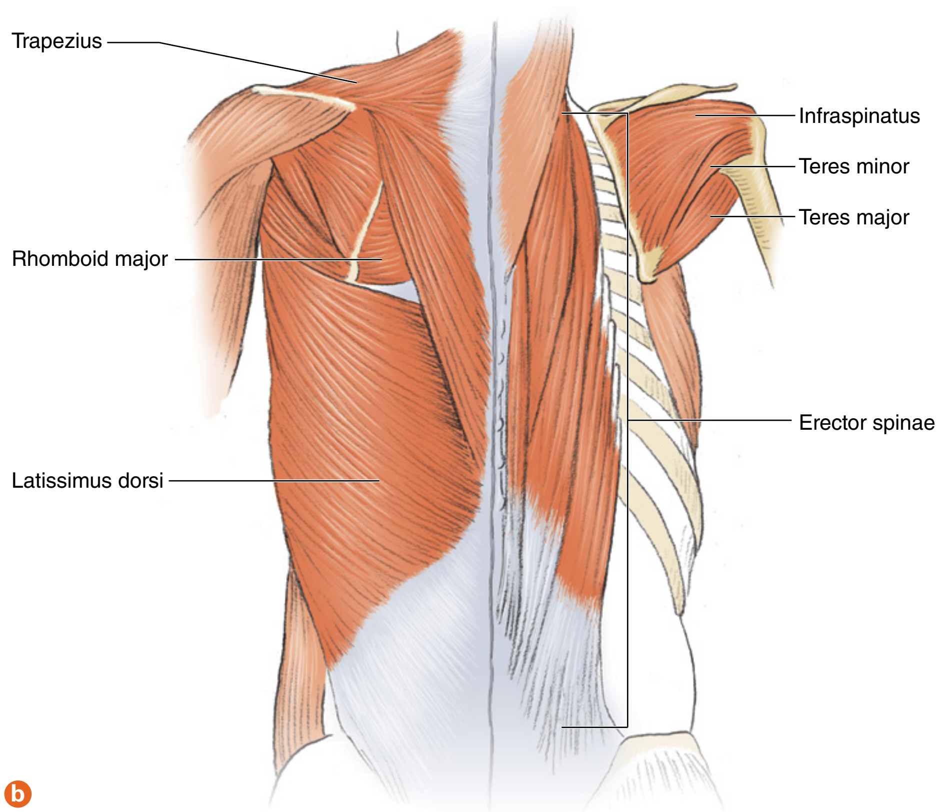


FIGURE 8.2 Upper torso: *(a)* front view and *(b)* back view.

This push–pull dynamic alternately fills the lungs with air and empties them in order to meet the body's oxygen needs.

In addition to their contribution to breathing, the muscles of the thorax play a limited but significant role in forward motion. The best way to appreciate this role is to view an approaching runner in slow motion. As the thigh moves forward with each stride, the pelvis rotates a little, first to one side and then to the other. This rotation twists the spine slightly and if left unchecked would cause instability in the abdomen and thorax. To prevent that instability, a small but significant tensing and relaxation of the thoracic musculature helps not only to maintain the vertical component but also to correct variations caused by forward motion up to 20 miles per hour (32 k/hr).

The muscles attached to the shoulders and the humerus—particularly the pectorals and the teres muscles—are also moved passively when the arms swing fore and aft with each stride. If they contract actively, they help move the upper arms to a small extent as they oppose the pull of the deltoid.

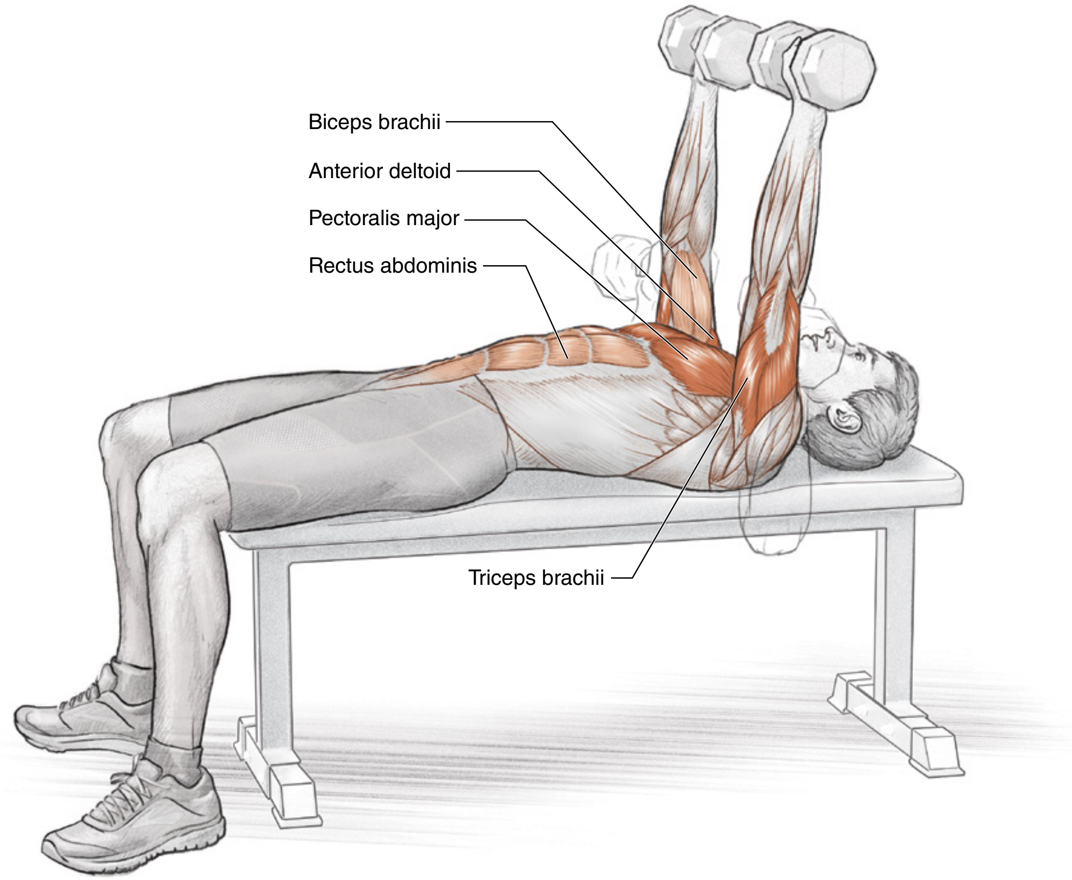
The importance of these muscles in running lies in the "weakest link" presumption—that the power of the runner depends not merely on the strength deployed but also on whichever facet of the running body tires first. If the muscles of the thorax are undertrained and therefore become fatigued, they are unable to perform their functions, which reduces the efficiency of the running action. This failure not only compromises the breathing action but also weakens the auxiliary actions that support the spine and aid in arm movement, thus leading to inevitable slowing.

Even after watching runners for many years, it is still surprising how many runners feel that they can improve only if they increase the pace or quantity of their training. Many do not realize that the limits on their running will *always* be related to the weakest part of the body. For instance, a runner's legs might be capable of running a mile in less than four minutes, but if the lungs lack the capacity to provide the legs with sufficient oxygen then the legs can do only what the lungs allow. To avoid this type of disparity, the diaphragm and the supporting muscles must be as fit and strong as the lower limbs. These muscles become fatigued by exercise in exactly the same way as do all others, and they need to be as highly trained as any other group of muscles involved in exercise. For that reason, the training exercises presented here should be considered as important as those prescribed for the legs.

SPECIFIC TRAINING GUIDELINES

Strength training for the chest and back will not make you bulky or impede your running performance unless you *want* to add a lot of mass. Most runners, of course, prefer to stay lithe, so they do three sets of a relatively high number of repetitions (12 to 15) with a relatively easy weight when performing the following exercises. This type of strength training does not mean that little strength is gained; it does mean (when it is combined with a decent amount of running volume) that little mass is added. Incorporating the following exercises into two sessions per week is enough to keep your chest and upper back strong, which will help support your proper running position and aid in respiration.

DUMBBELL PRESS



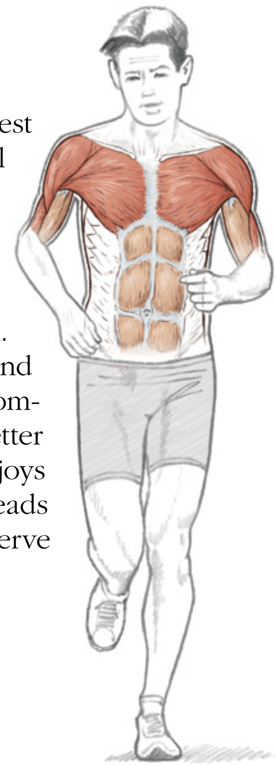
Execution

1. Lie supine (on your back) on a bench with your feet on the floor. There should be a small, natural bend in the lower back. A dumbbell should be held in each hand at chest level.
2. Press the dumbbells upward to full extension, then immediately begin lowering the dumbbells slowly to the original position.
3. Repeat the movement, keeping the back in a stable position against the bench.

Muscles Involved

Primary: Pectoralis major, triceps brachii, anterior deltoid

Secondary: Biceps brachii, rectus abdominis



RUNNING FOCUS

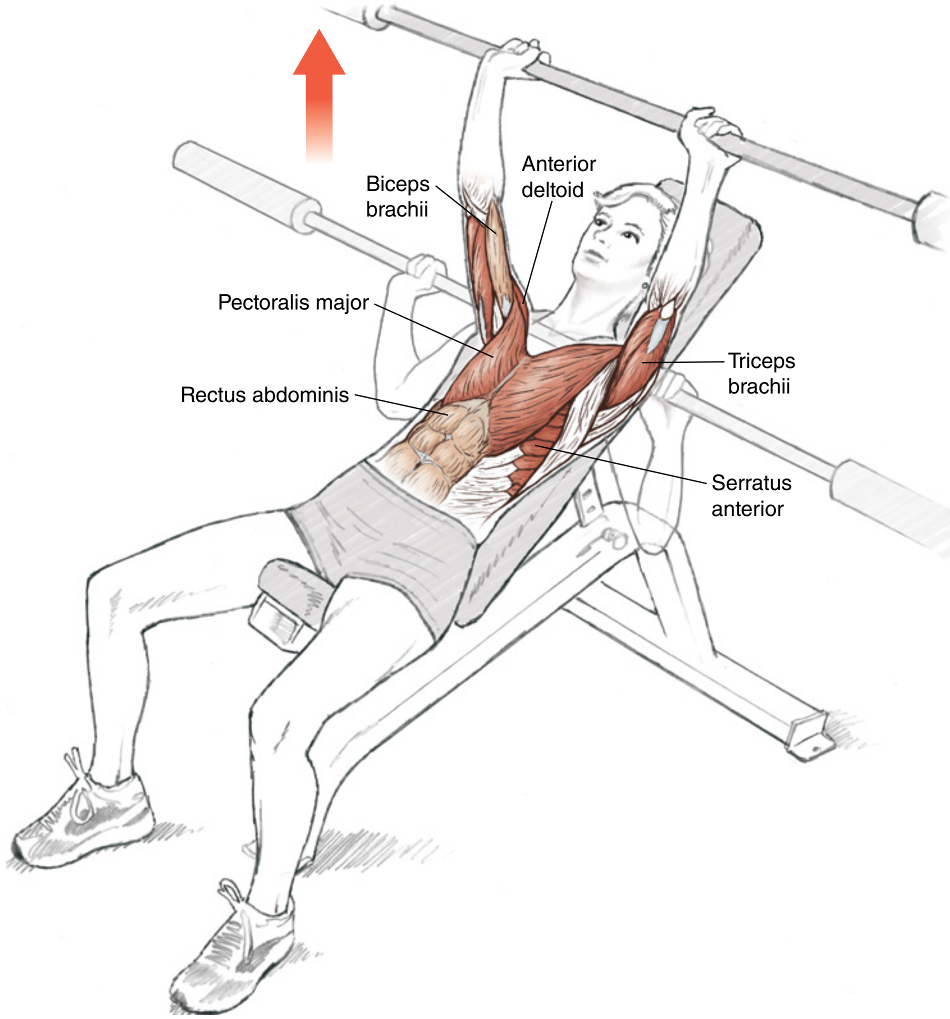
As mentioned earlier in the chapter, the muscles of the chest get fatigued by exercise in exactly the same way as do all other muscles. Fortunately, it is easy to develop these muscles through a simple exercise such as the dumbbell press. This exercise recruits the abdominal group more than the barbell bench press does because the independence of the two dumbbells causes the torso to require stabilization. Thus the exercise both targets the pectoral muscle group and uses the abdominal group as stabilizers. With stronger abdominal and pectoral muscles, a distance runner maintains better posture in the latter stages of a race or training run (and enjoys better respiration). Better upper-body posture, in turn, leads to a more efficient gait cycle, which helps the runner conserve precious energy.

VARIATION

Rotated Dumbbell Press

This variation especially develops the sternal head of the pectoral group, thus, fully developing the entire pectoral group.

INCLINE BARBELL PRESS



SAFETY TIP Use of a spotter is highly recommended to help with removing the barbell from the stays of the bench and with returning it there after the exercise is complete. Because of the inclined position used in this exercise, it requires more shoulder involvement—specifically, of the rotator cuff. If any pain is felt in the shoulder, discontinue the exercise and perform only the flat dumbbell press.

Execution

1. Lie on a bench inclined at 45 degrees with the arms extended almost fully. Grip the barbell with the hands a little farther than shoulder-width apart.
2. Fully extend the arms, removing the barbell from the rack. Lower the barbell in a straight line to the upper chest.
3. Press the barbell up, in a straight line, back to the original position without locking the elbows.

Muscles Involved

Primary: Pectoralis major, triceps brachii, anterior deltoid, serratus anterior

Secondary: Biceps brachii, rectus abdominis

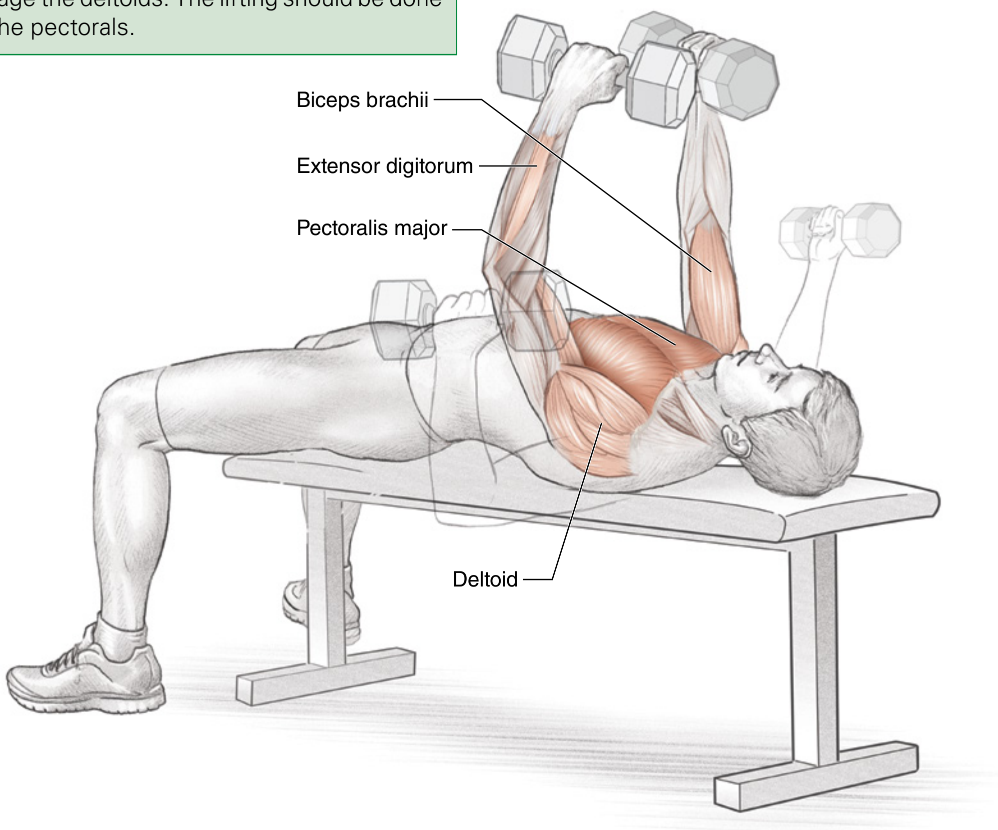
RUNNING FOCUS

Similar to the dumbbell press in the muscles engaged, the incline press also involves the serratus anterior, thus enhancing the development of the upper body. By using different exercises to stimulate muscle growth in the same area, runners can vary their strength training routine and thus keep the training regimen fresh.

DUMBBELL FLY

TECHNIQUE TIP

When returning the weight to the overhead position, do not push it with the hands or overly engage the deltoids. The lifting should be done by the pectorals.



Execution

1. Begin by lying supine on a bench with the feet on the floor. There should be a small, natural bend in the lower back so that it does not touch the bench. The arms are extended perpendicular to the body with a flex of 5 to 10 degrees in the elbows. The hands grip the dumbbells with the palms facing inward.
2. Lower the weight slowly, focusing on the stretch of the pectoral muscles while maintaining bent elbows, until the upper arms are outstretched and in the same plane as the benchtop.
3. Return the weight to the starting position as if hugging a barrel. Control the dumbbells so that they do not touch at the top but are separated by 2 or 3 inches (5 to 8 cm).

Muscles Involved

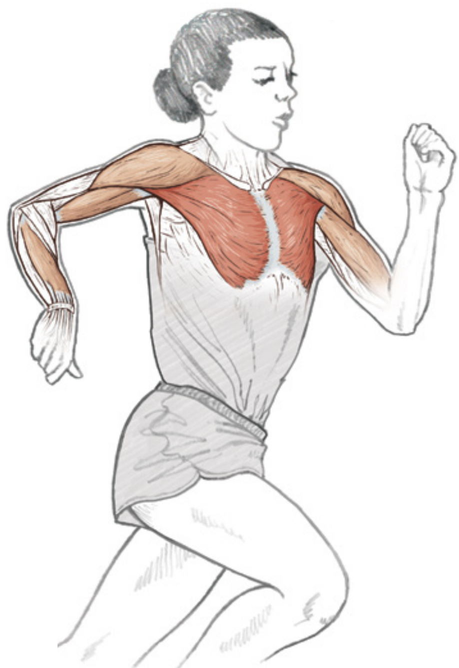
Primary: Pectoralis major

Secondary: Biceps brachii, deltoid, extensor digitorum

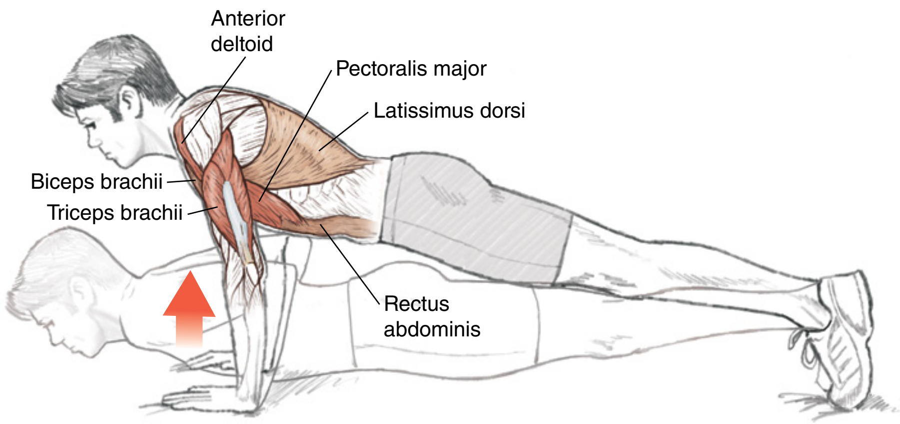
SAFETY TIP Note that the exercise begins with the arms extended, not outstretched. The reason is that lifting the dumbbells to begin the exercise can be difficult if heavy weight is used; in addition, starting in the outstretched position places the deltoids and biceps in an awkward position. To prevent injury, do not lower the arms past the plane of the benchtop.

RUNNING FOCUS

Strengthening the pectoral muscles has been noted as a benefit in all of the exercises presented in this chapter. However, the benefits of the dumbbell fly also include *stretching* the pectoral muscles—specifically during the negative, or lowering, phase of the exercise. This stretching helps expand the intercostal muscles between the ribs, thus allowing for better respiration. Essentially, the more the muscles of the chest are expanded, the easier it is to inhale oxygen. This effect is reflected in the large rib cages of elite marathoners, such as Ethiopian Haile Gebrselassie and American Ryan Hall. Their chests always seem expanded when they run, most likely to accommodate their exercise-enlarged lungs.



PUSH-UP



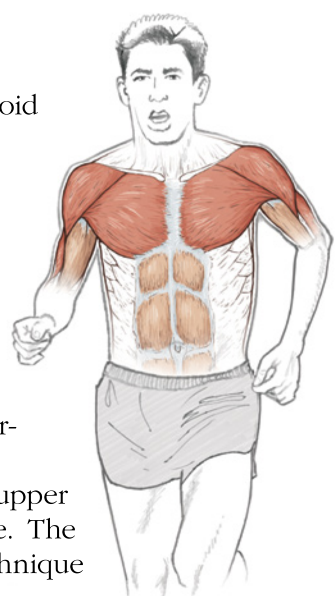
Execution

1. Start in a prone position with the arms bent and the hands on the floor and positioned slightly farther than shoulder-width apart in a straight line with the outsides of the shoulders.
2. Push away from the floor in a single, controlled movement, keeping the body in one slightly upward plane (from feet to head) until your arms are fully extended. Exhale while performing the push-up.
3. Lower your body slowly by bending at the elbows until the chest is parallel with and either touching or nearly touching the floor. Inhale during this phase of the exercise.

Muscles Involved

Primary: Pectoralis major, triceps brachii, anterior deltoid

Secondary: Biceps brachii, latissimus dorsi, rectus abdominis



RUNNING FOCUS

The push-up is the purest strength exercise. No machines. No weights (other than your own body weight). One fluid movement. It is not complicated unless you add variations (as in the incline push-up or the push-up on physioball), but it is a highly effective exercise for developing upper-body strength.

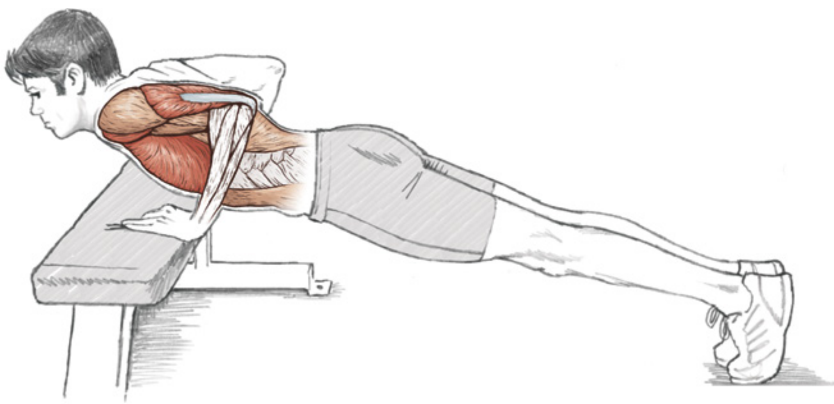
The push-up benefits a runner by strengthening the upper body and the abdominals, thus enabling proper posture. The exercise also reinforces correct posture because the technique used in completing it resembles the process of maintaining good positioning of the upper body during running.

Multiple sets of the push-up can be done, but as with any strength training activity, this exercise should not be performed daily. Instead, it should be done following a rest period that allows for mending of the muscle fibers involved.

VARIATIONS

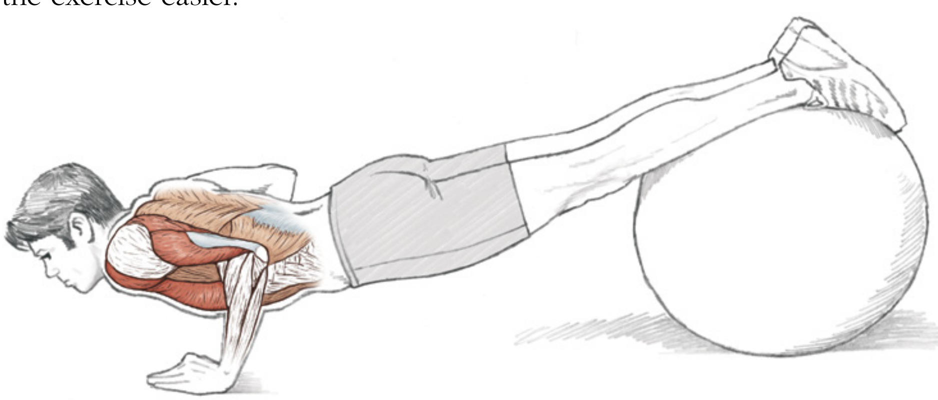
Incline Push-Up

The incline push-up shifts the emphasis of the exercise to the upper chest and shoulder muscles. Because it allows a greater number of push-ups to be performed, it is a good exercise to begin with if the regular push-up is difficult. One caveat: Because this exercise is easier, you may be tempted to accelerate the motion. This temptation should be resisted in order to avoid injury to the rotator cuff, which is more involved in the incline push-up than in the regular push-up.

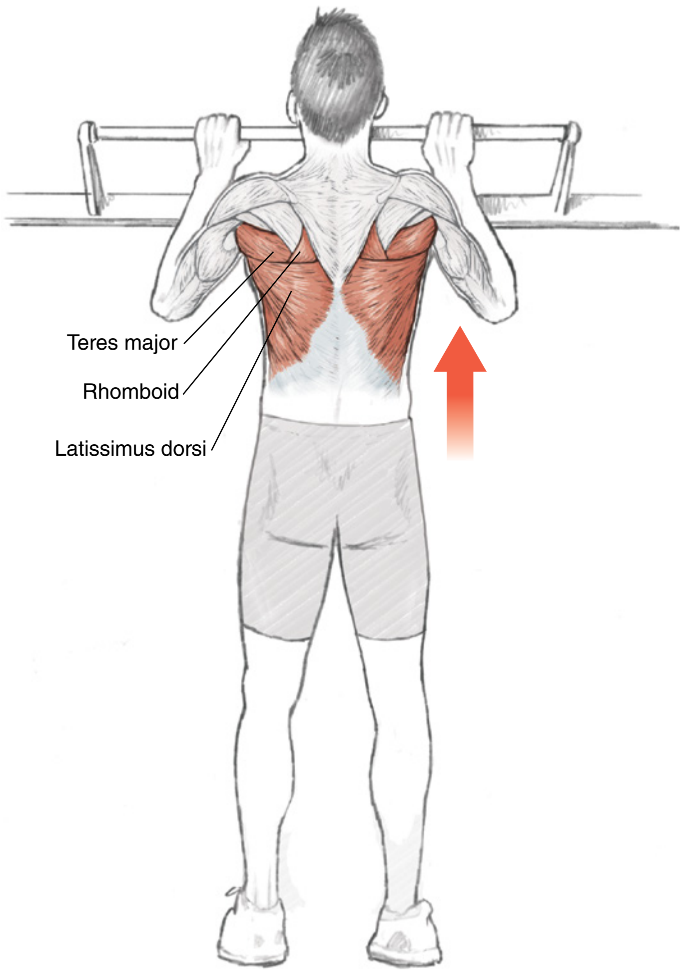


Push-Up on Physioball

As a decline push-up, this exercise shifts some of the emphasis to the upper back. Using a physioball while performing the exercise also requires core stabilization, which aggressively targets secondary muscle groups. When executing this push-up, try to keep your hips from sinking toward the ground; instead, maintain a rigid posture. If doing so is difficult, use a smaller physioball to make the exercise easier.



PULL-UP



Execution

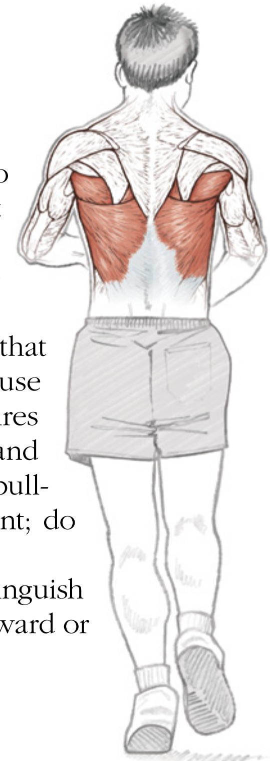
1. Use an overhand grip (palms forward) and hang from the pull-up bar, getting a full stretch.
2. Pull the body upward using a fluid motion.
3. When the chin reaches bar height, lower the body in a controlled movement back to nearly full extension of the arms. The feet should not touch the floor.

Muscles Involved

Primary: Latissimus dorsi, teres major, rhomboids

Secondary: Biceps brachii, pectoralis major

RUNNING FOCUS



The pull-up is the yin to the push-up's yang. It is simple to perform but provides major strength benefits. Specifically, it helps strengthen the upper back, and, as distance runners can attest, a strong upper back makes for better running posture during the later stages of a training run or long race.

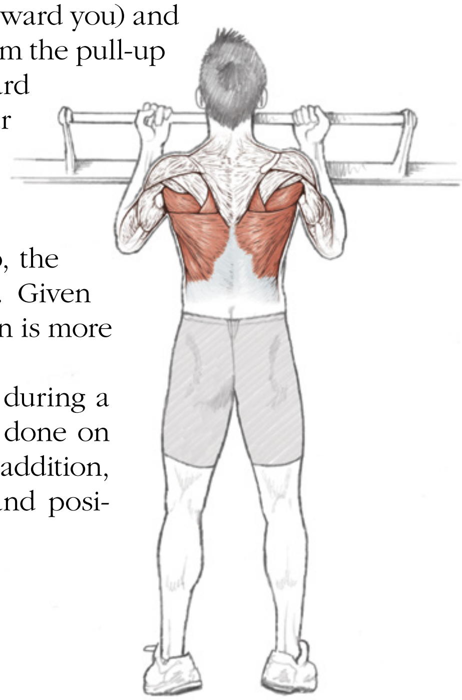
The pull-up is a difficult exercise—difficult enough, in fact, that the U.S. Marine Corps and other branches of the U.S. military use it to measure the fitness of their members (a perfect score requires 20 pull-ups in one minute). To aid in starting the exercise, stand on a box to begin the first repetition. Do only the number of pull-ups that can be performed with a fluid, controlled movement; do not wriggle or bounce.

The pull-up is often called *chin-up* instead. Some trainers distinguish between pull-ups and chin-ups based on the grip (palms outward or inward), but for others the difference is simply semantic.

VARIATION

Reverse-Grip Pull-Up

Use an underhand grip (with the palms facing toward you) and the hands placed shoulder-width apart. Hang from the pull-up bar, getting a full stretch. Pull the body upward using a fluid motion. Once the chin reaches bar height, lower the body in a controlled movement back to nearly full extension of the arms. The feet should not touch the floor.



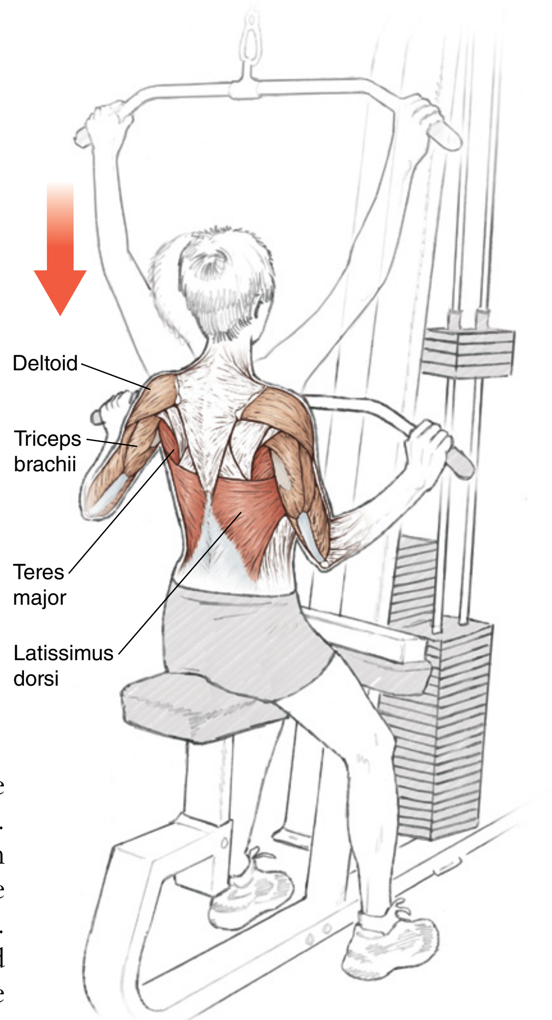
As compared with the overhand-grip pull-up, the reverse-grip version involves the biceps more. Given the relatively small size of the biceps, this version is more difficult because the biceps can fatigue quickly.

The two pull-up exercises can be alternated during a strenuous upper-back workout, or they can be done on different days as part of a general workout. In addition, pull-up machines offer multiple options for hand positioning.

MACHINE LAT PULL-DOWN

TECHNIQUE TIP

The lat pull-down causes significant muscle mass to develop in the upper back if heavy weight is used as resistance. Therefore, runners are advised to perform the exercise with lighter weight than the maximum and to complete multiple sets with relatively high repetitions.



Execution

1. Using a weight machine, face the bar with the legs under the pads. Grip the bar using a wide grip with the arms fully extended and the palms facing away from the body. The upper body is slightly rotated (shoulders back) to accommodate the exercise motion.
2. In one continuous motion, pull the bar down until the bar reaches the upper chest; keep the elbows back and the chest out.
3. Gradually allow the arms to return to full extension while resisting the weight during the negative phase of the exercise.

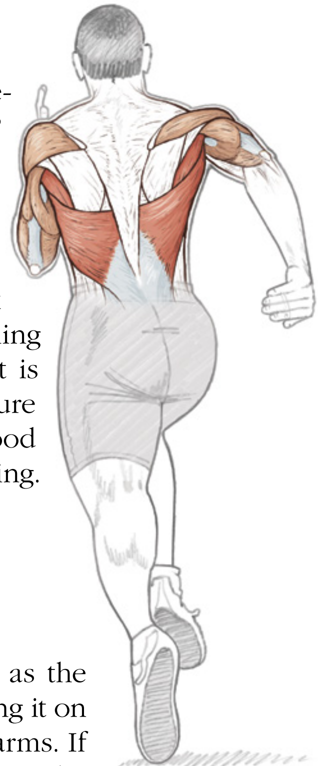
Muscles Involved

Primary: Latissimus dorsi, teres major

Secondary: Triceps brachii, deltoid

SAFETY TIP Do not pull the bar down behind your neck; doing so can cause neck problems or exacerbate existing neck (herniation) issues.

RUNNING FOCUS

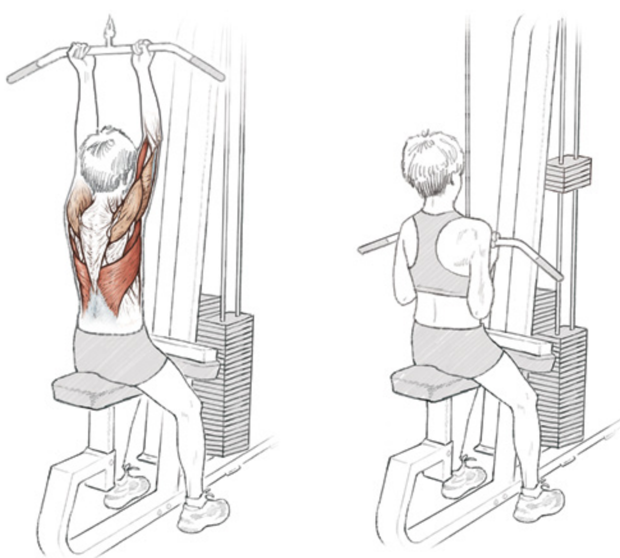


The lat pull-down motion is not a normal running movement, so how does this exercise aid running performance? As with the chest and upper-back exercises illustrated previously, the lat pull-down helps performance by strengthening muscles (specifically, the latissimus dorsi and teres major) that support and stabilize the body's thorax and aid in respiration and posture. Strengthening the upper back also helps counterbalance strength gained from performing exercises that target the chest, thus creating a torso that is balanced. It also helps with maintaining an erect posture throughout a lengthy training or racing session. This is a good exercise to perform during the introductory phase of training.

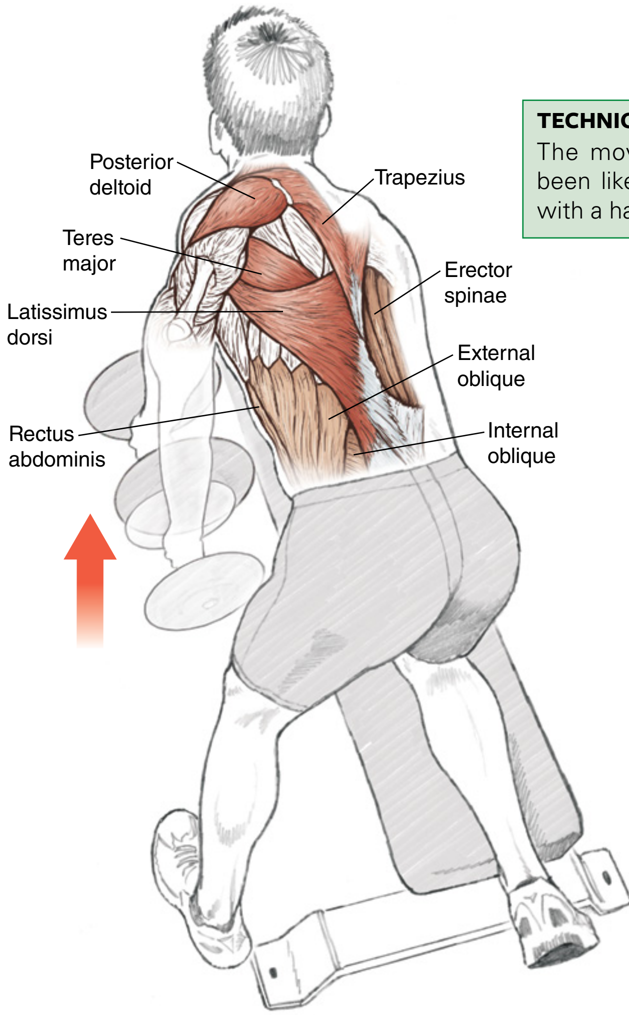
VARIATION

Reverse-Grip Lat Pull-Down

This exercise emphasizes the role of the biceps as well as the latissimus dorsi and teres major. We recommend completing it on a day when the workout is focused on strengthening the arms. If you perform the lat pull-down first, you may need to change the weight load to perform the reverse-grip variation since the latter minimizes the role of the larger shoulder and upper-back muscles.



SINGLE-ARM DUMBBELL ROW



TECHNIQUE TIP
The movement of this exercise has been likened to that of sawing wood with a hand saw.

Execution

1. Kneel with one leg on a flat bench. Use the same-side hand (the non-weight-holding hand) for support by placing it on the bench. The weight-holding hand is dropped below the benchtop by extending the arm.
2. Grip the weight and pull the dumbbell upward until the elbow is bent at a 90-degree angle. Use a smooth, continuous motion initiated by the muscles of the upper back and shoulder. Exhale while performing the row.
3. Gradually lower the weight along the same path traveled by the dumbbell on its way up.

Muscles Involved

Primary: Latissimus dorsi, teres major, posterior deltoid, biceps brachii, trapezius

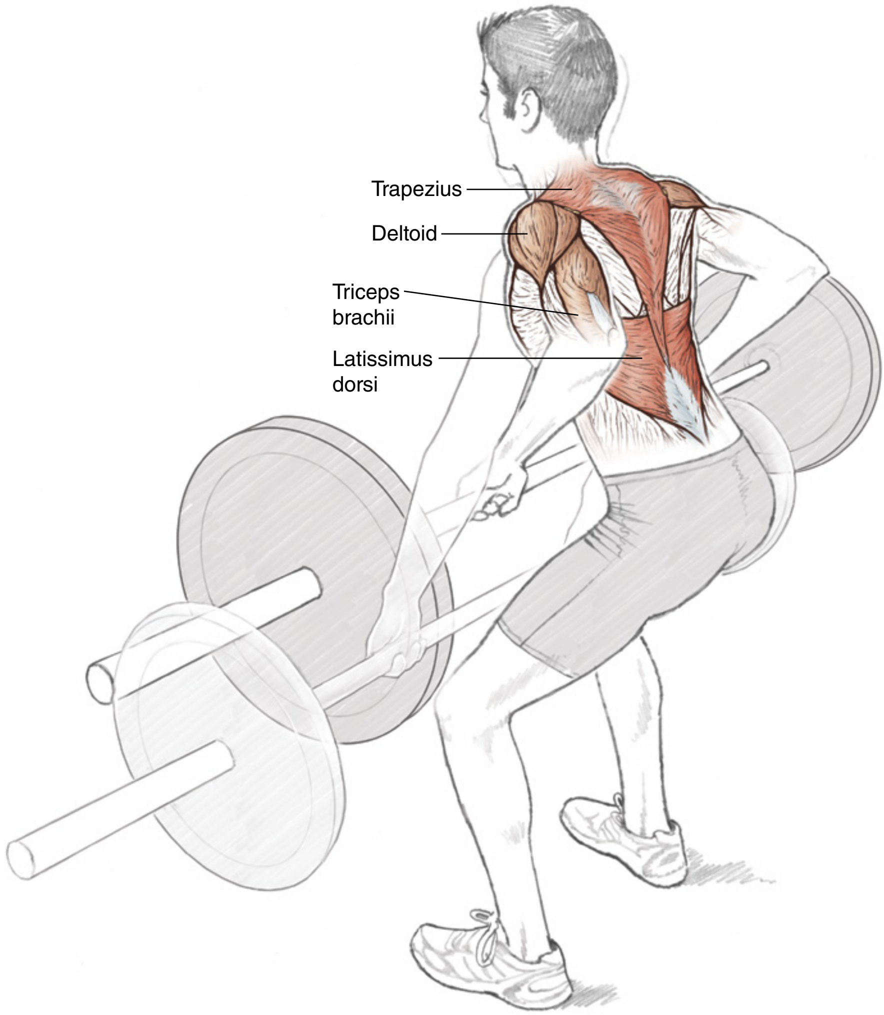
Secondary: Erector spinae (iliocostalis, longissimus, spinalis), rectus abdominis, external oblique, internal oblique

RUNNING FOCUS

This is an easy exercise to perform, and it benefits multiple muscles. Because a relatively heavy weight can be used (once good form is established), considerable strength can be gained. The development of the deltoid and trapezius help with head position and arm carriage. Specifically, strength in these muscle groups helps develop a powerful arm carriage during track sessions, fend off fatigue during longer workouts and races, and maintain good running form during trail runs on difficult (rocky or hilly) terrain.

An important element of this exercise is the isolation of the upper back and shoulder muscles involved. Although the abdominal group engages to stabilize the body, the emphasis should be placed on the role played by the latissimus dorsi, trapezius, deltoid, and biceps.

BENT-OVER ROW WITH BARBELL



Execution

1. Stand and lean forward at the waist with the legs shoulder-width apart, the knees slightly bent, and the arms hanging down. Grasp a barbell in a traditional grip with the hands shoulder-width apart.
2. Pull the barbell to the chest while still standing in a bent-over position (torso perpendicular to your legs) until your elbows are angled parallel to the chest.
3. Return the weight to the starting position and repeat.

Muscles Involved

Primary: Latissimus dorsi, trapezius

Secondary: Triceps brachii, deltoid

SAFETY TIP Always maintain the natural curve in the lower back while performing this exercise, especially if lifting heavier weight. Do not round the back.

RUNNING FOCUS

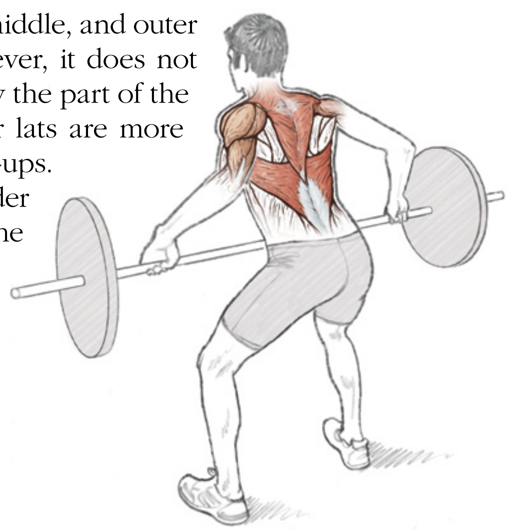
Muscle imbalances are prevalent in runners, predominantly among the four muscles of the quadriceps group, between the quadriceps group and the hamstring muscles, and, more generally, between the legs (i.e., left leg versus right). Muscle imbalances of the upper body often go unaddressed in strength training by runners because the practical shortcomings of such imbalances are not assumed to affect running performance. However, an imbalance between the "push" muscles of the chest and the "pull" muscles of the upper back can dramatically affect gait because the forward lean—or lack thereof—changes the degree of lift that the quadriceps group can generate during the forward swing phase. A lack of lift caused by too much forward lean can inhibit the runner's speed, especially during faster-paced training, and can also inhibit respiratory efficiency.

When speed is lost due to suboptimal lift in the gait cycle, the runner can compensate with faster turnover, but the resulting emphasis on aerobic capacity can adversely affect performance if the athlete's aerobic fitness is subpar. In this way, the anatomy of running plays a major role in performance despite its seemingly secondary role in fitness development. Specifically, if a large muscle group is strengthened (e.g., the pectorals through "push" exercises), the agonist muscles (in this case, those of the upper back) must be equally strengthened.

VARIATION

Wide-Grip Bent-Over Row With Barbell

A wider grip allows you to work the lower, middle, and outer latissimus dorsi muscles; in this case, however, it does not change the main muscle group worked, only the part of the muscle most impacted. Normally, the outer lats are more involved in back "pulling" exercises like pull-ups. Some athletes with longer arms prefer the wider grip because it feels more natural. Maintain the natural curve in the lower back.



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9

INJURY PREVENTION

If this book failed to address any potential downside to running, we would be doing you a great disservice. In fact, it would be naive in the extreme to imagine that one could run and exercise, no matter how efficiently, without meeting some of the pitfalls that almost every runner encounters at some point. Some of these issues lie beyond human control, but others are preventable if the long-term aim of the training program is addressed thoughtfully.

If you implement the exercises presented in this book, then the time you allocate both to exercise and to running will increase. When considering such increases, one commonly cited rule holds that we should never step up either the mileage or the time spent running by more than 10 percent per week. However, as mentioned in chapter 2, this "rule" is based on no substantiating evidence. Rather, it is conventional wisdom spread by word of mouth from coaches to runners and from one runner to another. Although this rule can't be applied in the initial stages of a training schedule, when fewer than 10 miles (16 km) per week are run, it should help prevent overuse injuries by graduating the increase in work as training progresses.

The best warning sign of injury is probably pain. It may appear, however, in a variety of forms, and it often occurs not at the true source but at a weaker part of the anatomy somewhere along the kinetic chain. In addition, pain does not always signal a problem. For instance, the discomfort that occurs during a tough training session may be a benign element of a process that leads to improvement in performance. Experienced runners learn to distinguish such sensations from pain that does not disappear when the exercise has ended.

Of course, injury can be induced by external factors, such as the running surface used and the clothing and shoes worn by the runner. The surface matters because runners' feet land with the force of three or four times their body weight, which affects the joints much more when landing on, say, concrete than when landing on a more forgiving surface such as sand, hard-packed dirt, gravel, or even asphalt. In addition, too many runners use only one side of a road, forgetting that the camber can pitch them toward the sidewalk and cause a pelvic tilt, which may result in a twisted lower back and strain the ligaments of the ankle joint and possibly the iliotibial band. These examples make clear that running demands thought. It is easy, for instance, to be dazzled by a new pair of running shoes only to have them cause blistering on the first use simply because you forgot to break them in. All shoes and clothing should be worn in but not worn out!

Because the diagnosis of an injury is likely to be complex, any unexplained pain or symptom should be assessed sooner rather than later by a professionally qualified doctor and assiduously researched by the runner. Having said that, common sense first-aid measures can and should be taken in the early stages of injury. It is sensible to follow the guidelines that any doctor would use. First, take a history by asking yourself these questions: Was the injury sudden, or did it build up over a series of runs? Does it cover a small area, or is it more diffuse? Does it hurt to touch? Does it disappear with rest? There are countless more questions you could ask; the goal is to help yourself think about the injury. Next, the injury should be looked at, because observation can distinguish characteristics such as asymmetry, swelling, and discoloration. If necessary, use a mirror. This stage of examination can include gentle palpation followed by both passive and active movement. By now, you may be able to make a differential diagnosis—that is, a choice between more likely and less likely causes. If the diagnosis is fairly certain, begin appropriate first-aid treatment; if not, further evaluation can be conducted in a visit to the doctor. If testing is called for, it may be possible to begin treatment while waiting for the test results; if the results alter the diagnosis, then treatment can be amended. The diagnosis and treatment phases of injury should be interrelated and reciprocal. In other words, if one is questionable or ineffective, then the other can be reviewed and reassessed.

COMMON RUNNING INJURIES

As you would expect, the areas of the body most likely to suffer as a result of running are the lower back, the groin, the leg muscles, the knee and ankle areas, and the feet. The tissues that suffer the most are bone, ligament, muscle, tendon, and fascia. Some choice!

A typical muscle tear is most likely to occur if the runner overstretches between two joints, especially if a halfhearted warm-up procedure has been used. More specifically, a blood vessel inside the muscle gets pulled beyond its limits, bursts, floods the area with blood, and stops bleeding only when the counterpressure exerted by the surrounding soft tissues (or strapping) is equal to that of the blood seeping out. The pressure of this bleeding causes pain in the soft tissues, which is always a good indicator of injury.

Cooling is a major factor that speeds up healing, so the rapid application of an ice pack to any acute injury (involving muscle or otherwise) is unlikely to do much harm. Moreover, if it limits the swelling, it may reduce the time spent in recovery. On the other hand, swelling, which results from the accumulation of fluid in tissue, not only brings an injury to light but also protects the affected body part and attempts to heal it. In this light, is it always a good idea to use ice therapy, which limits swelling by constricting the blood vessels and limiting blood flow?

Statistically, the most commonly injured sites among runners are the back and the knee. A runner's back pain is usually localized in the lumbar and sacral areas (figure 9.1). It often results from repetitive training with a lack or loss of low-back flexibility, accompanied by attempts to run through the pain. It may relate to poor posture, a real or artificial difference in leg length (which, as mentioned earlier, can occur when running on a cambered road), or a sudden switch to hill training. Any suggestion that the pain is referred down either leg or is associated with numbness or weakness of the limb could signify a more serious condition, such as a prolapsed intervertebral disc, for which a medical opinion should be urgently sought.

Much the same is true of the knee (figure 9.2). Prompt diagnosis is needed for an injury that is followed by swelling or locking within the joint, especially if this development occurs rapidly (over a few hours). Such an injury is not merely "runner's knee" (patellofemoral syndrome).

A traditional view of runner's knee holds that runners are more prone to patellofemoral pain as a result of the failure of the patella to glide through the center of the groove at the base of the femur. This dynamic may be caused by the alignment (or lack thereof) of certain parts of the knee anatomy. Specifically,

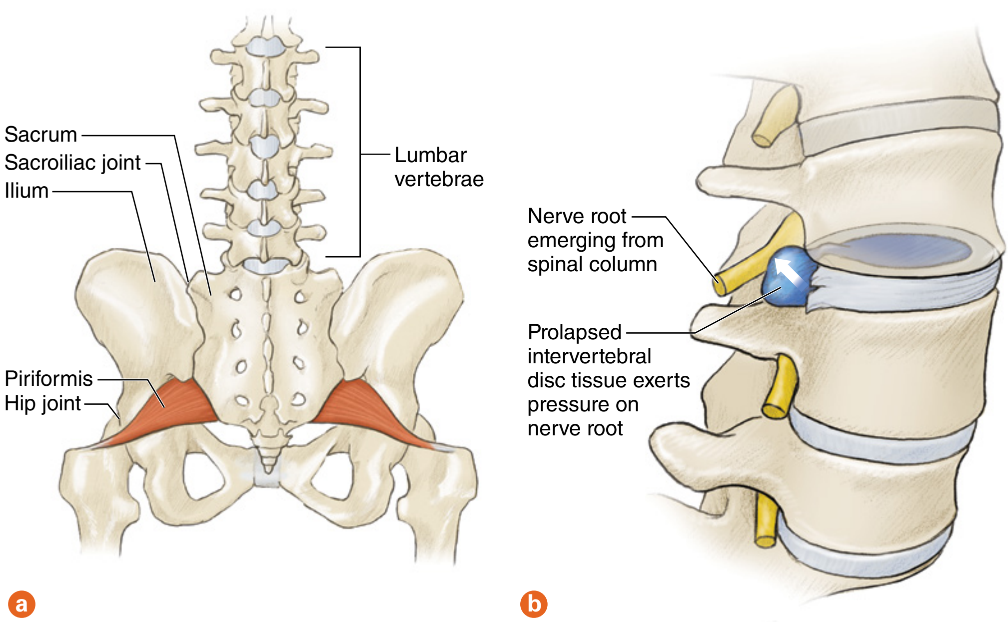


FIGURE 9.1 *(a)* Lumbar region of the back; *(b)* vertebrae.

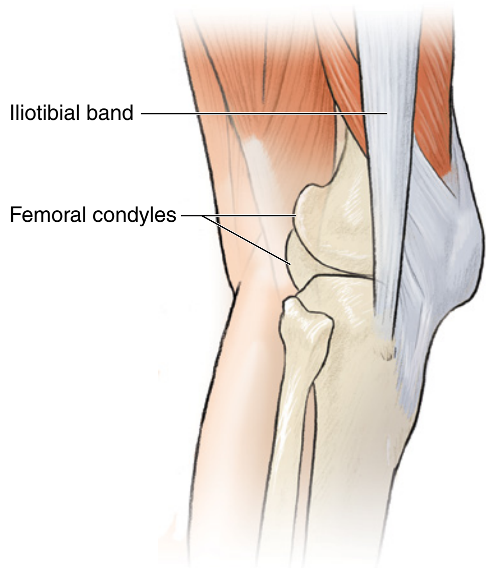


FIGURE 9.2 The knee.

when we stand, our knees and ankles are usually together, but the hip joints can be separated by 12 inches (30 cm) or more. As a result, when the quadriceps muscles contract, the patella is pulled laterally and twisted within the femoral groove. The pull of the outer quads may be counteracted by the vastus medialis, but it can do so only if it has been strengthened and developed sufficiently, which requires it to be exercised with the knee locked and extended.

If the pain can be localized, it is easier to diagnose the cause. Pain on the outside of the lower thigh likely results from iliotibial band (ITB) syndrome, in which this generally inelastic connective tissue rubs against the lateral condyle of the femur. If appropriate exercises to stretch it fail, then podiatric adjustment of shoes and insoles may provide a cure.

Self-diagnosis of any sporting injury is fraught with danger. Every injury differs in some way from every other one, and each requires individual assessment and management. Research conducted via the web is a legitimate method for understanding injuries but should *not* be used to diagnose an injury. It would also be irresponsible of us to attempt to manage injury in a book aimed at improvement. Therefore, the following paragraphs should serve simply to encourage you, the runner, to be aware that your body is not just a mean, well-oiled speed machine. Like all machinery, it may need a little fine-tuning!

Meniscus Tear

A meniscus tear is an injury to the cartilage that cushions the knee joint. The C-shaped medial (inside) and lateral (outside) menisci fit below the femur (the large bone of the upper leg) and are attached to the top of the tibia (the tibial plateau), which is the weight-supporting bone of the lower leg. Meniscal cartilage is not the same as the articular cartilage that lines the surface of the femur, tibia, and patella (kneecap) and allows the bones, lubricated with synovial fluid, to glide over each other when the knee joint is moved. Thus the term *cartilage tear* refers to the menisci, whereas *osteoarthritis* refers to the articular cartilage.

A meniscus tear often creates a locking sensation in the knee joint. Runners who have a torn meniscus often complain of tightness or instability around the knee joint, or even behind the knee. A physical examination should include the McMurray test, which involves manually manipulating the joint using rotation of a flexed and supported leg. Although it does not provide a final answer, the McMurray test can offer a preliminary evaluation; diagnosis typically involves an MRI.

Some meniscus tears are caused by trauma (such as a specific blow or awkward movement), whereas others result from chronic movements that cause fraying or tearing. Meniscus injuries can also have a genetic component.

Treatment for meniscus tears varies based on the severity and location of the tear, the age of the person, and the amount of physical activity desired after recovery. For instance, a flap tear is relatively easy to repair by means of arthroscopy; the flap of cartilage is excised, and full recovery normally takes less than a month. Once swelling is eliminated, exercise is typically green-lighted. A course of physical therapy should be prescribed to strengthen the hips, quadriceps, hamstrings, and calves before running is resumed.

If surgery is not an option—due to the location or severity of the tear—rest from physical activity is the first line of treatment, since it will allow the pain to subside. If rest proves not to be the answer, extensive and appropriate physical therapy is prescribed to increase strength and flexibility so that some running can be resumed. A small tear on the outer edge of either the medial or the lateral meniscus can typically heal on its own; in fact, it often goes undiagnosed because it causes little pain or discomfort. In contrast, a larger tear that causes significant pain and instability may require a partial or total meniscectomy—a removal of the cartilage.

Knee Osteoarthritis

During movement, every joint in the body produces synovial fluid, the joint lubricant, which reduces friction and helps minimize degeneration, especially within older joints. Still, as we age, the articular cartilage around the bones of the knee (tibia, femur, and patella) can begin to fray due to normal life activities such as standing, walking, and kneeling. Thus a majority of 70-year-olds have mild osteoarthritis in the knee or other joints simply from participating in life.

It has been rumored that running hastens the onset of knee osteoarthritis, but, thankfully, that notion has been debunked for most recreational runners. In fact, according to a National Runners' Health Study and a National Walkers' Health Study, the major determinants of knee osteoarthritis are genetic factors and excess weight, whereas mild to moderate running—15 to 20 miles (24 to 32 km) per week—may help *maintain* cartilage integrity (P.T. Williams, "Effects of Running and Walking on Osteoarthritis and Hip Replacement Risk," *Medicine & Science in Sports & Exercise,* 45[7] [2013]: 1292-1297).

The best way to avoid osteoarthritis, even if you are genetically predisposed to it, is to maintain the lowest healthy weight possible for your body by means of appropriate diet and exercise. Various treatments for osteoarthritis are promoted—for instance, capsaicin applications, hyaluronic acid injections, cortisone shots, and athletic taping. However, cartilage cannot be replaced, and these treatments do not address the cause of the pain—bone-on-bone abrasion—but merely mask the pain.

It is a commonly held notion that knee surgery means the appearance of osteoarthritis within a decade. While this may seem to be the case, the severity of osteoarthritis can vary based on genetic components, exercise, and body mass index (BMI). Ultimately, it appears that the best way for a runner to avoid or combat osteoarthritis is to keep running.

Metatarsalgia

Podiatric treatment may also help with the foot pain of metatarsalgia. With a dropped longitudinal arch (known as pes planus, or flatfoot), this extreme pain can result from constant landing on a particular bone in the foot and the resultant pull on the surrounding ligaments. The pain may be dissipated rapidly, however, by providing proper support to the arch through exercises for the intrinsic muscles of the feet (see chapter 4).

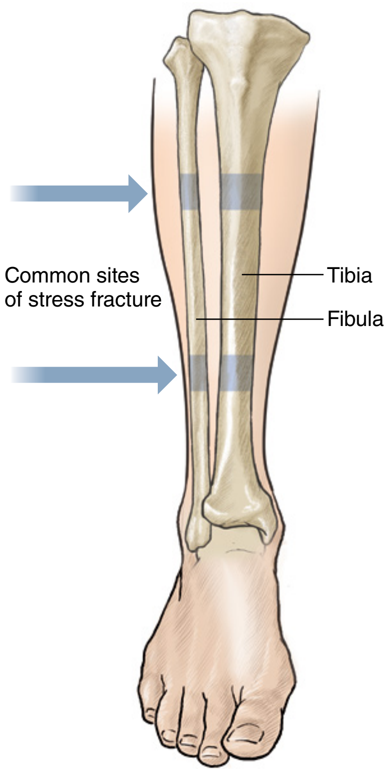


FIGURE 9.3 Common sites of stress fractures in the tibia and fibula.

Stress Fracture

Pain associated with bone is deeper and more resistant to analgesia than is pain from soft tissue. One particularly important cause of bone pain is the so-called "stress fracture." The most common sites of stress fracture in runners—the tibia and fibula—are shown in figure 9.3. This type of fracture can be compared to metal fatigue or the cracks that can occur in a china cup. The fracture is undoubtedly present, but the opposing surfaces remain together due to surface tension and the binding from soft tissues.

This type of injury is characterized by "crescendo" pain, which worsens as more distance is run. Most commonly, though not exclusively, it affects the lower leg or foot, and it stops only when the run ends. On the next run, it begins earlier and worsens sooner. If this symptom is ignored, it may proceed to a complete fracture, with all of the potential for disability of any broken bone, and it will take at least twice as along as a stress fracture to heal. Therefore, any runner with these symptoms who suspects a stress fracture is strongly advised to stop running immediately and seek a definitive diagnosis, which should involve either X-rays, scans, or, preferably, both.

Plantar Fasciitis

Plantar fasciitis can be such a painful condition that it often prevents any running at all. This sheet of fibrous tissue runs between the metatarsal heads and its insertion in the calcaneus (next to the Achilles tendon; figure 9.4). Its weakest part is found at the heel, where it becomes injured. The typical sufferer winces when the underside of the heel is even lightly touched. If the exercises presented in this chapter are ineffective, then a physician's steroid injection can produce a cure. A better long-term solution, however, is to seek knowledge of why the injury occurred and address that cause.

Why does plantar fasciitis occur? Like many running injuries, it happens due to some very specific reasons and some very general ones. Not every runner suffers plantar fasciitis for the same reason, but they all suffer. For instance, some runners wear stability shoes with a low arch when they have a high-arched foot. The discrepancy between arch height and arch support allows the plantar fascia to collapse or stretch into the empty space, which can result in micro tears in the fascia or pull the fascia away from its insertion into the bottom of the calcaneus. In another example, runners with chronically tight calf muscles

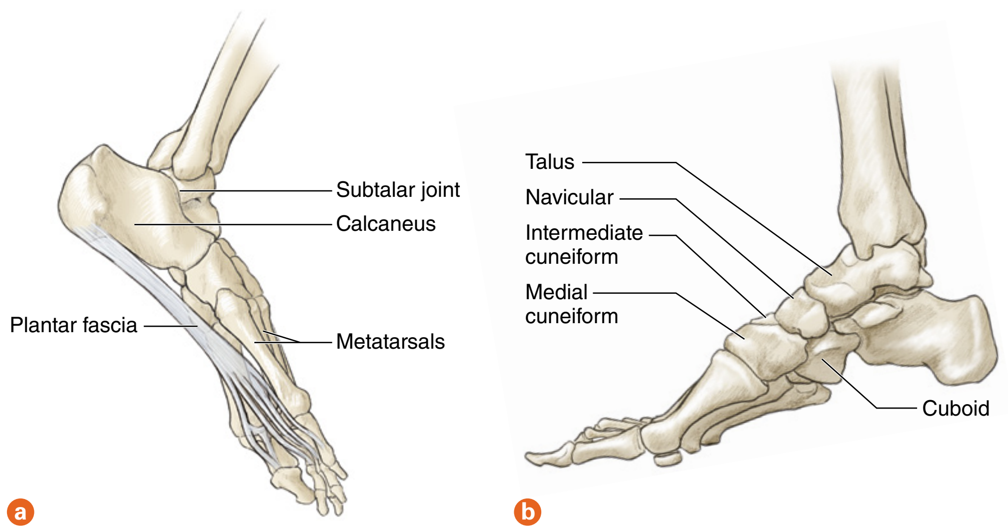


FIGURE 9.4 Foot: *(a)* underside showing plantar fascia; *(b)* medial side.

may develop plantar fasciitis because the tight calf muscles tighten the Achilles tendon to which they are attached, which in turn causes the ankle to lose its ability to dorsiflex. This lack of dorsiflexion can cause the plantar fascia to tighten and become inflamed.

In short, the potential causes of plantar fasciitis are practically limitless. In contrast, the treatment options are rather limited—and not always effective. Cortisone shots may work, but where exactly should the shot be administered, given that the fascia extends for the length of the foot and into the heel? Another treatment method involves night splinting to stretch the calf muscles; however, because the calf muscles and the Achilles tendon don't connect directly to the plantar fascia in adults, this approach does not provide a guaranteed fix. Adding an arch support may also makes sense, but is the added arch support shaped correctly, and does it change the foot's natural biomechanics?

Most likely, the wisest way to address plantar fasciitis is to stretch and strengthen the entire foot, the ankle, and the calf complex. Ideally, rolling the foot over a hard rubber ball, a golf ball, or another round surface with sufficient density would possibly eliminate some fascial adhesions and serve as a good way to start rehabbing the injury. Also, some of the exercises included in chapter 4 (such as the heel raises and the dorsiflexion with ankle weights) can help stretch and strengthen the plantar fascia and, one hopes, enable pain-free running.

Achilles Tendon Injury

If an Achilles tendon (figure 9.5) or any other tendon is injured, healing is delayed by the poor blood supply to this type of tissue. Although diagnosis may not be difficult—the tendon becomes locally tender and stiff, especially if inadvertently over-stretched—there is much dispute about treatment. Current opinion tends toward a regimen of extensive stretching and eccentric contractions after some healing has occurred. (It is *not* a good idea to immediately stretch a muscle or tendon that has already been stretched to the point of microtearing.) This stretching needs to be repeated endlessly, even after a cure has been effected, in an attempt to prevent recurrence. To be of value, a stretch should be uncomfortable rather than painful; it should also be held for 15 to 30 seconds and should never done in a jerky manner or an unstable position (such as doing a quadriceps stretch while standing on one leg).

ACTIVE RELEASE TECHNIQUES

Currently, the most successful treatment approach for runners with soft-tissue injuries involves the use of Active Release Techniques (ART). As the name suggests, the premise of ART is to manipulate soft tissue through active tech-

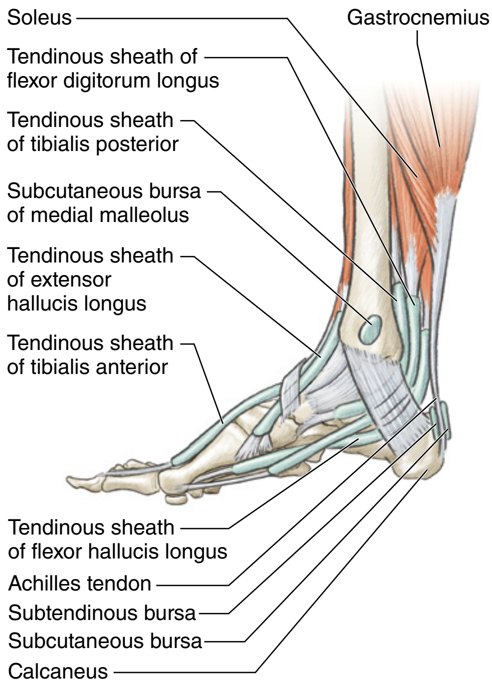


FIGURE 9.5 Tendons, bones, and muscles of the lower leg and foot.

niques that allow it to function as intended without being compromised by scar tissue or fascial adhesions. ART is the most effective way of removing scar tissue adhesion in musculoskeletal complaints. Such adhesion reduces a muscle's force production, thus making it functionally weak, and decreases joint range of motion. ART removes scar tissue adhesion by using a combination of compression and specific tension either on a single muscle or between adjacent anatomical structures.

To illustrate, let's consider the psoas muscle, which is the most important hip flexor and the most common muscle involved in hip-related running injuries. If injured, it may present as functionally weak and decrease hip-joint extension during gait. In ART treatment for the psoas, the patient lies on one side with the top knee bent. As the ART practitioner applies contact tension on the adhesion, the patient actively extends the hip with a straight leg. The developed end-range tension breaks lose the adhesion, and this release can be felt by both the patient and the provider. Depending on the severity of the condition, immediate results may be obtained, thus resolving deficiencies in joint-complex strength and range of motion.

GRASTON TECHNIQUE

The Graston Technique is another method for eliminating fascial adhesions and scar tissue that prevent soft tissues from functioning naturally. This technique differs from ART in that it relies on metal tools rather than the therapist's hands; thus it is classified as an instrument-assisted soft tissue mobilization (IASTM) treatment. Its roots can be traced to the ancient Chinese technique of gua sha. Patients should expect discomfort when the Graston instruments are rubbed on the targeted soft tissue. Often, the treated area becomes immediately discolored due to blood flow to the treated tissue, but this effect should not be confused with the capillary rupture that causes bruising. The rubbing technique, while painful at times, is superficial, and the discoloration should resolve within 48 to 72 hours.

FOAM ROLLING

Foam rolling has become de rigeur for runners; indeed, foam rollers seem to be viewed as a must-have for all serious runners, as well as those who want to be serious. Essentially, foam rollers offer a solid platform over which to rub large muscle groups. They are typically used when so-called “knots” of thickened soft tissue need to be treated. Unfortunately, due to the force required and the method’s lack of precision, foam rolling cannot fully deform a muscle or break up small fascial adhesions. Trigger-point balls work better for small areas, but, again, the pressure is insufficient to create significant relief.

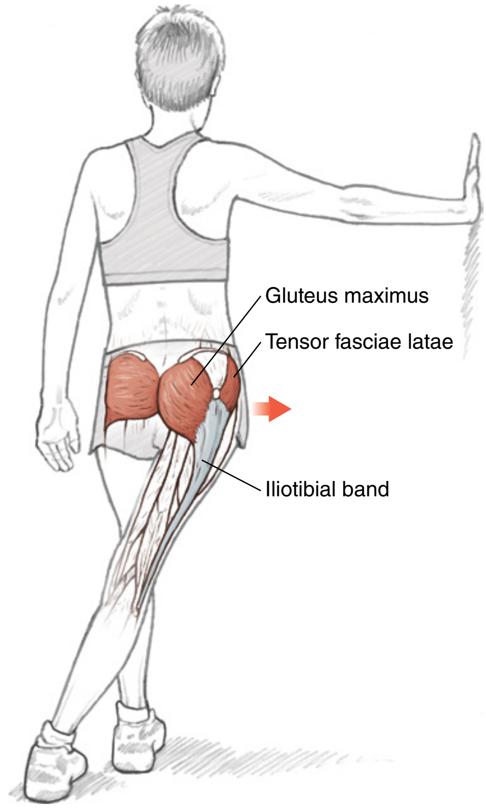
Foam rolling is also used as a warm-up technique in which the relevant body part is maneuvered over the foam roller to create blood flow to the targeted area. If you wish to try foam rolling, practice on an uninjured area in order to get a feel for the technique. If foam rolling is used in conjunction with other treatments for injury repair, an initial caress with the roller should produce discomfort; as pressure progresses, soreness will increase accordingly, but it should subside as the massaging effect takes hold. As with most things in life, there is no substitute for experience and practice.

SPECIFIC TRAINING GUIDELINES

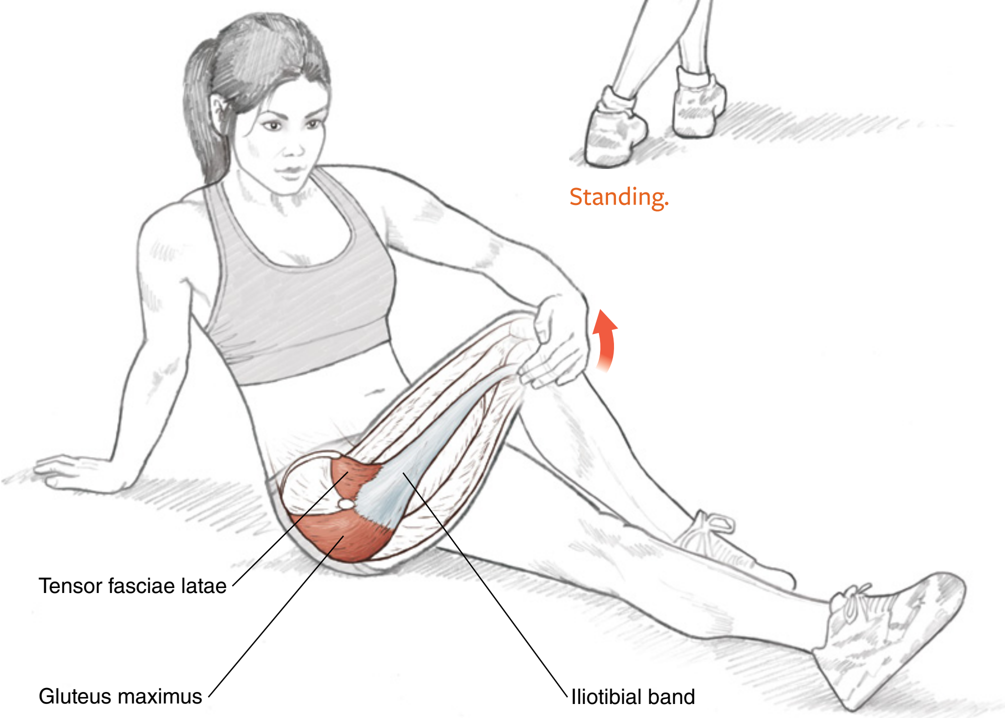
Warm up by doing some light walking or running (if the injury allows) before performing a stretch. If the stretch is part of rehabilitation for a tight iliotibial band and running is not an option, walk or perform a warm-up exercise for the legs for 10 minutes in order to promote blood flow.

There are many supposedly therapeutic treatments for running injuries, and many methods for performing those treatments. For example, the role of stretching in running training is widely debated. Among other questions, most runners ask experts how often to stretch, which body parts to stretch, and how long to hold the stretches. Because this book emphasizes anatomy and strength training, we largely leave stretching up to you as a topic for in-depth examination on your own. We do offer some best practices, but we also believe in your authoring your own system for running training. With that in mind, try the strength training and rehabilitation exercises presented in this book and supplement them with others that have proven successful in your experience.

ILIOTIBIAL (ITB) STRETCH



Standing.



Sitting.

Execution for Standing ITB Stretch

1. Stand next to a wall and cross the outside leg in front of the inside leg (closest to the wall). Press a hand against the wall for support.
2. Lean the inside hip toward the wall, touching the wall if possible. Both feet should remain flat on the ground.
3. Hold the static stretch for 15 to 30 seconds. Repeat multiple times, then switch sides.

Execution for Sitting ITB Stretch

1. Sit on the floor with one leg extended and the other leg crossed at the knee, with its knee in the air, and its foot firmly on the ground. The opposite hand supports the knee joint.
2. Gently press the outside of the bent knee toward the opposite armpit.
3. Hold the static stretch for 15 to 30 seconds. Repeat multiple times, then switch sides.

Muscles Involved

Primary: Gluteus maximus, tensor fasciae latae

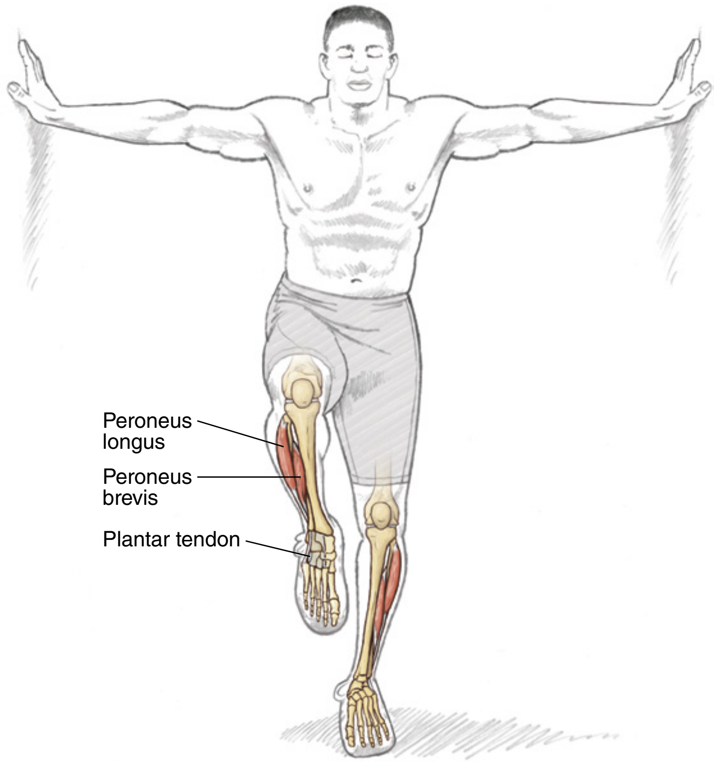
Soft Tissue Involved

Primary: Iliotibial band

RUNNING FOCUS

A tight iliotibial band normally results from supination, not overpronation. The inversion of the foot can cause tight calves, lateral knee pain, and tight iliotibial bands. Even pronators who are overcorrected by their stability shoes or orthotics, essentially creating underpronation, can suffer from this injury. The standing and sitting iliotibial band stretches help prevent the rubbing of this thick band of soft tissue over its attachment at the lateral femoral epicondyle. These stretches can be performed several times per day.

PROPRIOCEPTIVE STANDING BALANCE



Execution

1. Stand between two walls, one to the left and the other to the right. Extend the arms sideways at shoulder height for balance. Do not use the walls to balance unless doing so is necessary in order to prevent falling.
2. Lift one knee until it is bent at a 90-degree angle at hip height and the tibia is positioned perpendicular to the femur. Close your eyes.
3. Hold the position for 15 to 30 seconds. Lower the leg and repeat with the other leg. Perform multiple repetitions.

Muscles Involved

Primary: Peroneus longus, peroneus brevis

Soft Tissue Involved

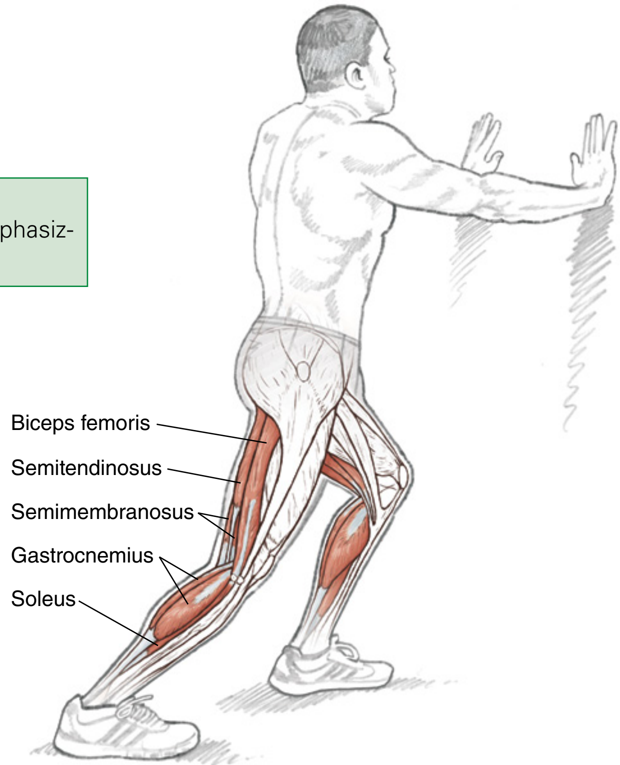
Primary: Plantar tendon

RUNNING FOCUS

This exercise includes both a physiological and a neuromuscular component. It may take a while to establish proper balance, but the foot and lower leg are working to find equilibrium, so the exercise is productive even if you don't find balance immediately.

STANDING CALF STRETCH

TECHNIQUE TIP
Avoid bouncing and overemphasizing the Achilles tendon.



Execution

1. Stand facing a wall with one leg extended backward and its foot planted on the ground. The other leg is flexed at the knee with its foot planted on the ground straight down from the hip. The arms are extended forward at upper-chest height and positioned shoulder-width apart. Place the hands on the wall.
2. Press gently into the wall and gradually press the heel of the extended leg into the floor. A stretch should be felt through the length of the gastrocnemius.
3. Stretch statically for 15 to 30 seconds and repeat multiple times, then perform on the other side; alternatively, switch legs after every repetition.

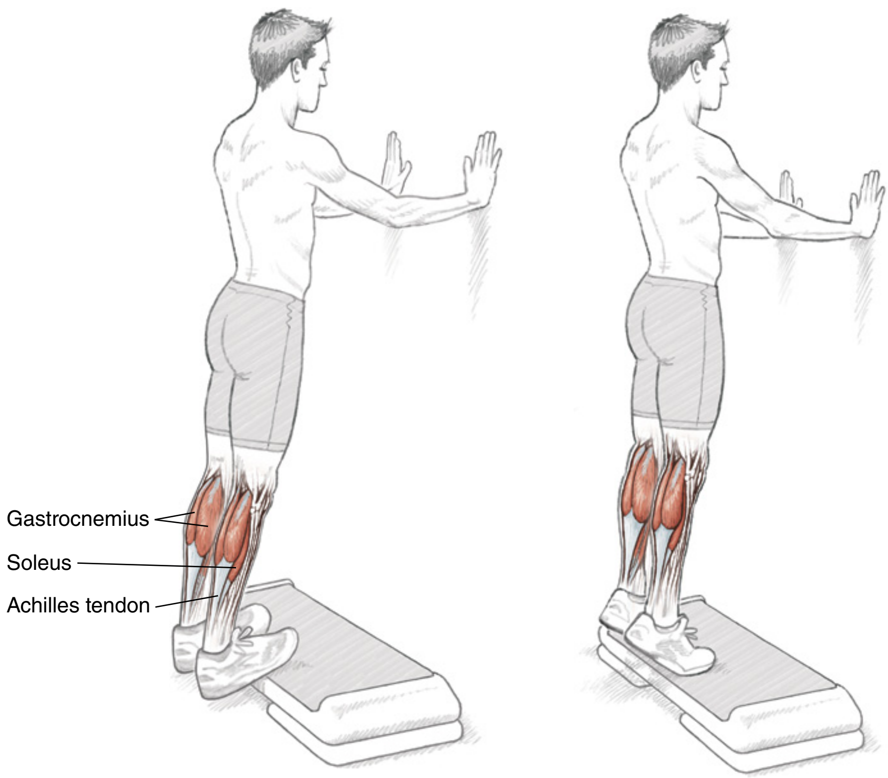
Muscles Involved

Primary: Gastrocnemius, soleus, hamstrings (semitendinosus, semimembranosus, biceps femoris)

RUNNING FOCUS

Runners with neutral or underpronated biomechanics often suffer with tight calves. This stretch helps alleviate the pain of a chronically injured calf and also helps prevent calf injuries by keeping the muscle supple.

STANDING HEEL RAISE WITH ECCENTRIC COMPONENT



Start position.

Finish position.

TECHNIQUE TIP
Do not forcefully dorsiflex; doing so places too much stress on the Achilles tendon.

Execution

1. Stand with both feet on a step and the heels extended off of the step. The hands are pressed against a wall in front.
2. Rise onto the metatarsal heads of both feet to full extension (plantar flexion).
3. Lower gradually to full extension (dorsiflexion).

Muscles Involved

Primary: Gastrocnemius, soleus

Soft Tissue Involved

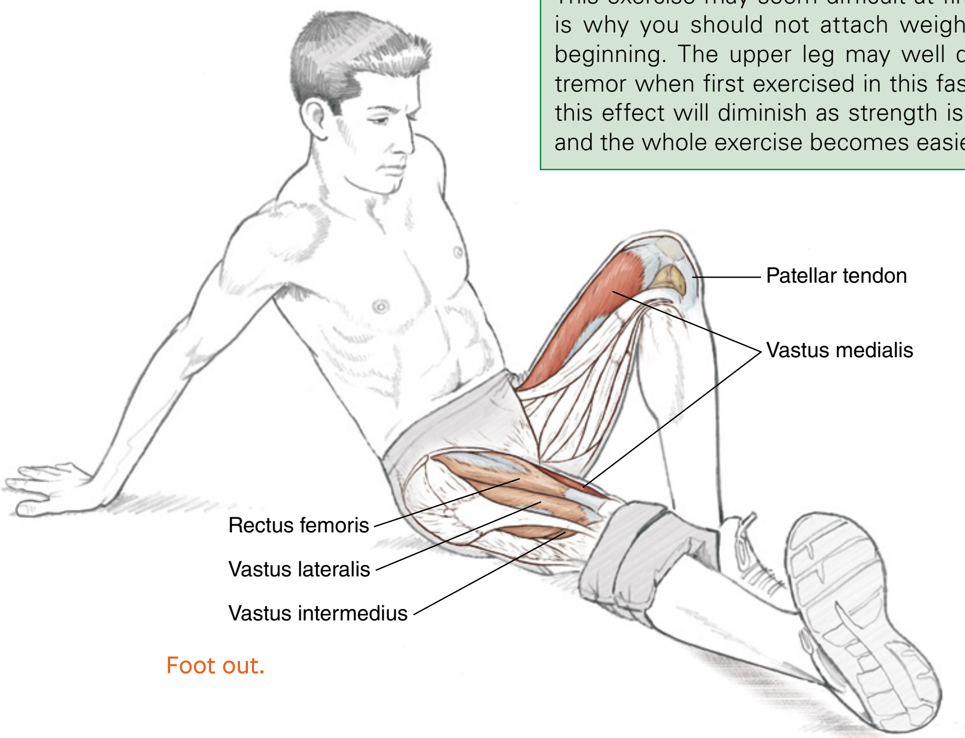
Primary: Achilles tendon

RUNNING FOCUS

This exercise both concentrically contracts (shortens) the calf muscle during plantar flexion and eccentrically contracts (lengthens) the muscle during dorsiflexion. As mentioned in chapter 4, the inclusion of an eccentric, or negative, component adds value to this exercise for the calf and the Achilles tendon. Studies have found that performing exercises with an eccentric component shortens the time required to heal from an injury.

SEATED STRAIGHT-LEG EXTENSION

TECHNIQUE TIP
This exercise may seem difficult at first, which is why you should not attach weights in the beginning. The upper leg may well develop a tremor when first exercised in this fashion, but this effect will diminish as strength is acquired and the whole exercise becomes easier.



Foot out.

Foot straight up.

Foot in.

Execution

1. Sit on the floor with your arms behind you for support and one leg outstretched. In the early stages, do not attach weights to the working leg; as you become more adept, you may incrementally add up to 10 pounds (4.5 kg) in order to improve strength.
2. Turn the foot outward and slowly lift the leg, keeping it locked straight but not hyperextended at the knee, until it is no more than six inches (15 cm) off the floor. Hold for 10 seconds, then, equally slowly, lower the ankle to the ground and rest.
3. Repeat the exercise 10 times per each foot position (a total of 30 reps). The change in foot position works the muscles of the quadriceps evenly. Switch legs and repeat.

Muscles Involved

Primary: Vastus medialis

Secondary: Rectus femoris, vastus intermedius, vastus lateralis

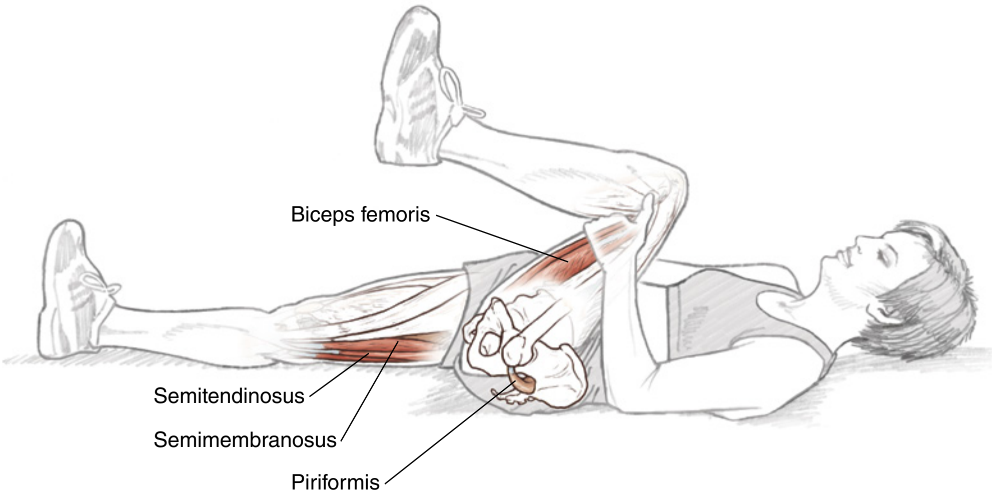
Soft Tissue Involved

Primary: Medial collateral ligament, patellar tendon

RUNNING FOCUS

If sports medicine clinics banned runners with knee pain, they would be very lonely places! Part of the reason is that too many coaches place far too much emphasis on general quadriceps development and fail to comprehend the role played by the vastus medialis in stabilizing the knee and preventing patellofemoral pain. This exercise provides the most effective way to increase strength and power in this muscle in order to ward off the demon of anterior knee pain.

KNEE-TO-CHEST STRETCH



Execution

1. Lie on your back on a firm but comfortable surface.
2. Use the quadriceps to lift and bend the knee to 90 degrees. Grasp the area behind the knee with both hands and pull it toward the chest so that you feel a pulling sensation in the lowest part of the back and upper buttocks. At the same time, resist the urge to flex the other hip; instead, push it down onto the surface.
3. Hold the position for 15 to 30 seconds and repeat no more than five times. Alternate with the other leg. This exercise can be performed two or three times per day.

Muscles Involved

Primary: Hamstrings (semitendinosus, semimembranosus, biceps femoris)

Secondary: Piriformis, erector spinae (iliocostalis, longissimus, spinalis)

RUNNING FOCUS

The lower back is usually ignored as a vital element of running until pain develops. By then, it may be too late to correct. This exercise and those that follow give the lower back both flexibility and strength, which are particularly important when climbing or descending hills. If the back can accommodate the changes in gradient, then stride length will also be increased by flexibility in the hips and lower back. As with all stretching exercises, the aim here is to achieve discomfort without pain.

WALL PRESS

Execution

1. Stand about 18 inches (45 cm) from a wall with the feet shoulder-width apart and the toes pointed inward.
2. Press the pelvis to the wall, adjusting the distance from the wall and the angle of the toes to gain the best stretch of the soleus. Keep the heels on the floor.
3. Hold the stretch for 15 to 30 seconds, then repeat.

Muscles Involved

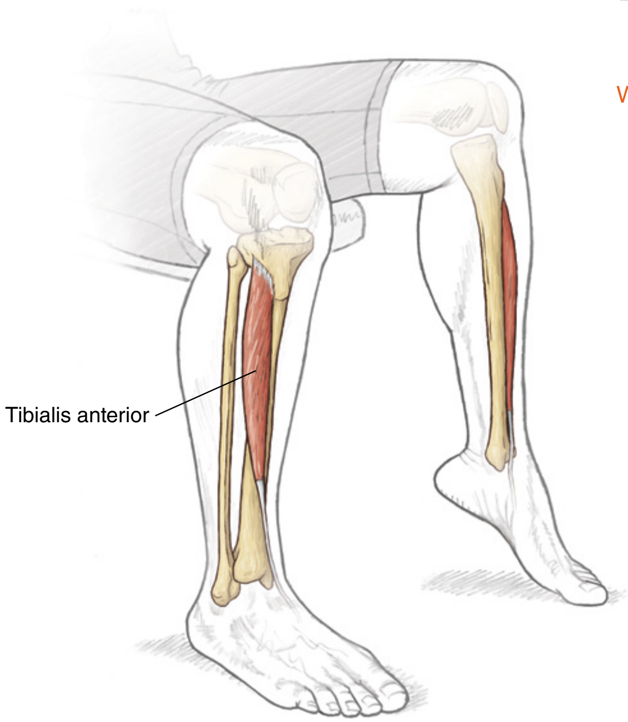
Primary: Soleus, gastrocnemius, tibialis anterior

RUNNING FOCUS

Shinsplints, or diffuse anterior lower-leg pain, can be related either to soft tissue or to bone (in particular, the tibia). Both problems usually stem from overpronation; however, the soft-tissue variety is normally associated with midfoot horizontal-plane abduction. This exercise can help prevent muscle pain in the anterior compartment of the gastrocnemius. The exercise can be performed multiple times per day and is effective when done regularly.

ANKLE PLANTAR FLEXION


With band.



Execution

1. Sit upright on a comfortable, hard-backed chair. The foot of the exercising leg is initially flat on the floor and the knee is bent at about 45 degrees, depending on the height of the chair. Raise the heel off the ground, then invert the foot as though pointing the toes like a ballet dancer. Hold the position for 15 seconds and repeat up to 10 times, two or three times per day, with each foot.
2. Place the chair in a position where a piece of flexible elastic (such as a TheraBand) can be attached in a loop to an immovable object on a wall. Sit in the same stretched position described in step 1 and put the elastic around the midfoot farthest away from the wall. Use the band as resistance to ease the foot farther into inversion and pull against it in order to strengthen the tibialis anterior muscle. Hold the position for 15 seconds and repeat up to 10 times, two or three times per day, with each foot.

Muscle Involved

Primary: Tibialis anterior

RUNNING FOCUS

The importance of the tibialis anterior muscle lies in the flexibility that it gives to the ankles and feet. It is very involved in increasing stability when running on uneven terrain because it helps adjust the position of the foot and therefore the leg. As a result, any prolonged hill or undulating rough ground brings it into increased use. If left untrained, it tires rapidly and slows the runner down, while also increasing the risk of a sprained ankle. When strengthened, however, it helps limit pronation and supination.

BALL ROLLING

Execution

1. Stand with the arms hanging by the sides and with good posture for balance. Press one foot down forcibly on a lacrosse ball (if desired, a golf ball can be used instead for more precision).
2. Roll the ball underneath the foot, both forward and backward and from side to side. Emphasize the arch area of the foot ending at the metatarsal heads and pay special attention to the heel.
3. Roll the ball under one foot for 30 seconds before switching feet.

Muscles Involved

Primary: Plantar fascia

RUNNING FOCUS

Both plantar fasciitis and this specific rehabilitation exercise were described earlier in the chapter. Ball rolling can also be used for prehabilitation if you have had plantar fasciitis or have complained of a tight feeling in your arch or a painful feeling in your heel when you first stand and begin walking after sleep. Using a golf ball allows you to target a more precise area of the plantar fascia, but a golf ball tends to squirt out from under the foot much more easily than a lacrosse ball does. One of the best parts of this exercise is that you control the amount of pressure applied to your foot by increasing or decreasing the amount of weight placed on it.

10

ALTERNATIVE TRAINING ACTIVITIES

Chapters 4 through 8 address strength training and the effects of properly performed resistance exercises on specific parts of the anatomy. This chapter covers nontraditional forms of running training that complement the strength training exercises detailed in the previous chapters. Specifically, this chapter examines water running, running on an antigravity treadmill, and altitude training as performance-enhancing training tools for runners. These alternative forms of running conditioning can help boost performance in two ways: reducing injury risk and increasing aerobic capacity.

Water running and antigravity treadmill running reduce the risk of injury to the musculoskeletal system posed by the repetitive, high-impact action of running. By substituting either of these alternatives for a land-running session, you can save the body from experiencing countless tons of force without losing cardiorespiratory stimulation, thus helping you withstand the impact of accumulated training miles. These types of training can also improve running economy and (when performed at the appropriate time in the recovery process) aid in recovery from injury.

High-altitude training (and living—not merely using a hypoxic mask) can dramatically increase a runner's aerobic capacity. Incorporating these elements into a training plan increases a runner's red blood cell count and allows more oxygen to be transported to the muscles via capillary development.

WATER RUNNING

Most runners have been introduced to water running as a rehabilitative tool for maintaining cardiorespiratory fitness after incurring an injury that precludes land running. However, runners should not assume that injury rehabilitation is the only benefit offered by aquatic training. To the contrary, running in water—specifically, deep-water running (DWR)—offers a great tool for preventing overuse injuries associated with a heavy volume of aerobic running training. Also, because of the drag associated with running in water, it incorporates an element of resistance training that does not exist in traditional running training.

An alternative to DWR is shallow-water running, but its benefits tend to be related to form and power. Although improvement of these elements is important, it comes at a cost because shallow-water running requires touching the bottom of the pool; in other words, it includes an impact component (albeit one that is mitigated by the density of the water). Thus, for instance, shallow-water running could pose a risk of injury to a runner who is rehabbing a lower-leg injury. More important, balance and form are easier to attain in shallow-water running because of the foot plant involved; therefore, it engages fewer core muscles than DWR does to center the body. In addition, the moment of contact provides a resting period that does not exist in DWR. For our purposes here, then, all water-related training exercises focus on DWR.

In performing a DWR workout, proper body positioning is important (figure 10.1). The depth of the water should be sufficient to cover most of the body. Only the tops of the shoulders, the neck, and the head should be above the surface of the water. The feet should not touch the bottom of the pool. In addition, runners tend to have more lean body mass than swimmers do, which makes them less buoyant; therefore, a flotation device is necessary. If a flotation device is not worn, body position can be compromised, which may place undue emphasis on the muscles of the upper body and arms in order to keep the body afloat.

Once buoyed in the water, assume a body position similar to that of land running (for an example of *poor* body position during DWR, see figure 10.2.). Specifically, in proper positioning, the head is centered, there is a slight forward lean at the waist, the chest is "proud" (expanded), and the shoulders are pulled back (not rotated forward). The elbows are bent at 90 degrees, and the shoulders drive the movement of the arms. The wrists are held in a neutral position, and the hands, though not clenched, are more closed than when running on land in order to push through the resistance of the water. This aspect of the positioning can be facilitated by the strength gained from performing wrist curls and reverse wrist curls (see chapter 7).

Leg action in DWR is more akin to faster-paced running than to general aerobic running because of the propulsive force needed in order to overcome the resistance caused by the density of the water. The knee should be driven upward to an angle of about 75 degrees at the hip. The leg is then driven down to almost full extension (avoiding hyperextension), then pulled upward directly under the buttocks, after which the process is repeated with the other leg.

During the DWR gait cycle, the feet change position from no flexion (imagine standing on a flat surface) when the knee is driving upward to about 65 degrees of plantar flexion (toes down) at full extension. This foot movement against resistance both facilitates the mechanics of running

FIGURE 10.1 Proper body position for deep-water running.

form and promotes joint stability and muscle strength as a result of overcoming the resistance caused by drag.

Due to the unnatural training environment (water) and the resistance created when driving the arms and legs, improper form is common when beginning a DWR training program. Specifically, it is common to make a punting type of motion with the forward leg instead of snapping it down as shown in the B motion in chapter 1. This error results from fatigue of the hamstrings due to water resistance. To correct it, rest at the onset of the fatigue and don't perform another repetition until the time goal is met. Do *not* try to push through it. You won't gain fitness, but you will gain poor form.

Figure 10.3 shows a DWR technique that most closely resembles the dry-land running form. It is the best technique for facilitating proper running form while training in deep water. A high-knee alternative does exist (figure 10.4), but it is less effective in mimicking the nuances of proper running form. Instead, it more closely resembles the form used on a stair-stepping exercise machine. There is little running action other than the lift phase and therefore very little muscle involvement.

DWR is effective because it elevates the heart rate similarly to dry-land running. In addition, because of the physics of drag, it requires more muscular involvement, thus strengthening more muscles than dry-land running does without risking the corresponding overuse injuries associated with such training. Specifically, it eliminates the thousands of impact-producing foot strikes incurred during non-DWR running.

FIGURE 10.2 Incorrect body position for deep-water running.

FIGURE 10.3 Deep-water running—traditional form.

DWR is easily integrated into a running training program, either as a substitute for an aerobic run, a lactate or $\dot{V}O_2$max effort, or as a supplemental workout (such as a second running workout of the day). Because pace can be easily controlled by speeding up or slowing down leg turnover, it is simple to adjust one's effort based on heart rate or perceived effort. Studies have found that heart rates during water running are about 10 percent lower than during land running, so a heart rate of 150 beats per minute (bpm) during water running equates to a rate of 165 bpm on land. Also, perceived effort is greater in water because of the combination of greater muscle involvement and the warm temperature of most pools.

FIGURE 10.4 Deep-water running—high-knee form.

Because running in a pool for an hour is boring to most runners, we recommend 50 minutes in a pool as a good substitute for an on-land easy run. The emphasis in DWR training should be placed on fartlek and interval-type efforts; in addition, multiple intense efforts akin to speed work on land can be performed in a given week because of the lack of ground impact. Two sample DWR workouts are presented in the following subsections.

Sample Lactate Workout

The goal of this workout is to elevate the blood-lactate accumulation. Muscle fatigue should be greater at the end of each successive repetition because the one-minute rest period does not allow full recovery. As a result, this is not an easy workout, nor does it constitute a true speed session.

Warm-up: 15 min easy running + 4 × 0:30 at 5K race pace (perceived effort)

2 × 10 min at 10K race pace (perceived effort) with 1 min recovery jog

1 × 15 min at 10K race pace (perceived effort) with 1 min recovery jog

Cool-down: 10 min easy running

Sample $\dot{V}O_2$max Workout

The goal of this workout is to simulate 5K race effort. Because pace cannot be replicated in a pool, the workout emphasizes perceived effort. To make this determination, heart rate can be used, or exact effort can be substituted if you know your training zones from a lactate threshold (LT) test and you own a waterproof heart rate monitor. Rest is given to allow for proper form on each repetition. As in running on dry land, body position is an important component of running efficiency in DWR. Good body position (as described and illustrated earlier in this chapter) leads to a more productive workout. This exercise requires a moderately hard effort from a trained runner and a hard effort from a beginner.

Warm-up: 15 min easy running + 4 × 0:30 at 5K race pace (perceived effort)

5 × 2 min at 5K race pace (perceived effort) with 2 min recovery jog

3 × 3 min at 5K race pace (perceived effort) with 3 min recovery jog

3 × 2 min at 5K race pace (perceived effort) with 2 min recovery jog

Cool-down: 10 min easy running

ANTIGRAVITY TREADMILL

An antigravity treadmill "unweights" the runner by off-loading a percentage of body weight by means of an inflatable "bag" that envelops the runner's legs (but does not impede proper running motion). The degree of unweighting can be adjusted to accommodate an injury concern or to allow the runner to run faster than is normally possible. This process enables neurological changes and cardiovascular adaptations that could not occur with slower, traditional, land-based training.

For example, a well-trained runner might perform a land-based track interval session as follows:

8 × 400 m at 90 sec (pace of 6 min per mi) with 1 min recovery

In contrast, if the runner uses an antigravity treadmill at 85 percent of body weight, the pace may be more like 82 to 84 seconds for 400 meters. Due to the off-loading of 15 percent of body weight, the runner can go faster than is possible either on land or on a traditional treadmill. The neurological changes associated with this change in pace enable the runner to adapt both to the increased pace (because biochemistry allows for respiratory adaptation) and to a much faster turnover rate. More important, the dramatic reduction in landing load also reduces recovery time, which allows the runner to complete more intense workouts in a shorter window of time.

Antigravity treadmills also serve as a useful tool for injured runners who want to run while rehabbing from, say, a foot injury. Rather than running faster than usual, the runner in this scenario can complete the same workout at 75 percent of body weight, thus reducing the landing force of body weight by 25 percent. In this case, then, the antigravity treadmill is used not for getting faster but for maintaining speed and fitness despite injury.

Of course, antigravity treadmills are typically found not at gyms but in physical therapy and rehabilitation centers. Beginning at $35,000, they are also not often purchased for home use; however, if an antigravity treadmill is available, it provides a useful training tool for preventing injury, rehabilitating after injury, and enhancing performance.

ALTITUDE TRAINING

At an altitude greater than 2,000 feet (600 m) above sea level, the performance of an unacclimated runner is negatively affected due to a lower blood oxygen level. It isn't that there is less oxygen at higher elevation but that the air pressure is lower, which results in less oxygen being passed through the lungs into the blood.

How does this condition aid a runner who lives or trains at altitude? At first, it doesn't. In fact, until the body adapts to the diminished blood oxygen level, you can expect much slower times at altitude than at sea level. In particular, performance is inhibited by a decrease in $\dot{V}O_2max$—the maximum amount of oxygen that one can use during intense training. Specifically, various studies have indicated a 2 percent drop in performance for every 1,000 feet (300 m) above the first 1,000 (there is little or no perceptible change in performance from sea level to 1,000 feet). Therefore, a 7:00 mile performed at sea level (or at an elevation of 1,000 feet or lower) translates to about 7:34 at 5,000 feet (1,500 m); similarly, an 8:00 mile performed below 1,000 feet would become an 8:48 mile at 6,000 feet (1,800 m). These are big changes, and failing to adjust one's pace accordingly will lead to major disappointment—and a good bit of suffering!

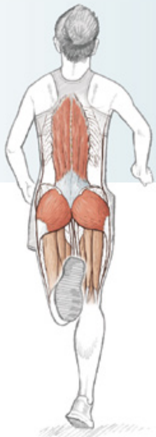
After months of training, however, your body adapts to the lack of oxygen in the air by producing more red blood cells (to carry more oxygen) and more capillaries (to carry the increase in red blood cells). In addition, your lungs get bigger! Despite these physiological changes, however, it is difficult if not impossible to run the same times at altitude as one can below 1,000 feet for distance workouts or races. Instead, the benefit of training at altitude is found in races and training performed at sea level. Once the air pressure increases with the decrease in elevation, all of the benefits accrued at altitude remain: More capillaries, more red blood cells, and more oxygen mean more fitness! Unfortunately, this benefit is short-lived (measured in weeks).

One proposed method for mimicking the conditions of altitude training is to use a hypoxic (oxygen-limiting) mask during training. However, no studies have proven that this approach aids performance. In fact, it detracts from performance by limiting the user's ability to run as far or as fast as would be possible without using the mask. Since no physiological adaptations for distance runners have been found after prolonged use of such a mask for exercise, it seems rational not to wear one.

OTHER ALTERNATIVES

All alternative forms of aerobic training (e.g., cycling, swimming) can benefit a runner by increasing aerobic capacity and neuromuscular development. Some claims of performance enhancement for runners have been made by practitioners of CrossFit and HIIT (high-intensity interval training) workouts. These claims have not undergone lengthy peer-reviewed studies; however, for some runners, a different form of running training will be successful.

Ultimately, the body adapts to changes in stimulus. To become a better runner, then, one needs to run a little farther or a little faster than before. This running can be performed in a pool, on an antigravity treadmill, or at altitude (or in a pool or on an antigravity treadmill at altitude!). Adding the strength training program that we have suggested will undoubtedly aid running performance for all the reasons we have listed. However, a well-conceived alternative form of strength training may also prove beneficial by providing a different stimulus. In the end, you are an experiment of one. Best practices, like those explained in this book, are best practices for the majority of runners, but each runner is unique, and understanding your uniqueness is critical to understanding how to train most effectively.



11

GEAR AND ADVANCEMENTS

Runners who perform the strength training regimen outlined in chapters 4 through 8, conform their training to the tenets explained in chapter 2, and perform the injury-prevention exercises described in chapter 9 can still be stymied in their efforts to improve running performance. The reason can be something as simple as wearing the wrong training shoes or the wrong orthotic device for one's foot type. Therefore, this chapter presents an overview of how and why running shoes are constructed for particular sets of biomechanics and how runners can choose the right footwear and orthotics for their specific needs. It also examines the role played by technology, which is not a mere fad in the running world.

WHY WEAR RUNNING SHOES?

Running shoes work for running because they are biomechanically nuanced, terrain specific, and designed and manufactured to meet the demands of bearing three to four times the body's weight on impact. In practical terms, running shoes are designed on lasts, or forms, that model the human foot. These lasts take shapes ranging from straight to curved, including variations in the degree of curve, which enable the shoes modeled on them to fit the various foot shapes of runners.

The term *last* also refers to the methodology of construction. More specifically, a *combination-lasted* shoe is one in which the upper fabric underneath is stitched to a cardboard heel to provide stability. In contrast, a *slip-lasted* shoe is one in which the upper is stitched to directly to the midsole, thus ensuring flexibility. And a *full-board last* (cardboard from heel to toe) is the most stable manufacturing technique but is currently almost nonexistent in shoe manufacturing.

Curved slip-lasted shoes are designed for higher-arched, rigid feet, whereas straight combination-lasted shoes are designed for flatter, more flexible feet. Flat feet tend to pronate more—that is, roll inward more at the rear foot (a motion controlled by the subtalar joint)—than high-arched feet do. The rate and amount of pronation can be limited by using straight-lasted shoes with the aid of stability devices embedded in the midsole. Conversely, runners who underpronate should wear curved or slightly curved slip-lasted shoes, which allow the foot to generate as much pronation as possible in order to aid in shock absorption.

Many runners err in choosing shoes because they do not know what foot type they have. For instance, if an underpronator trains in stability shoes, then predictable injuries will occur, such as calf pain, Achilles tendinitis, and iliotibial band syndrome. Similarly, if an overpronator trains in a cushioning-only shoe, then stress injuries (including fractures) are likely to occur in the foot, tibia, and medial knee. For most runners, a qualified employee at a running specialty store can evaluate foot biomechanics, possibly with aid of a treadmill. The employee can then recommend multiple shoe models that will, at least in theory, prevent injury and provide a pleasurable run. Occasionally, evaluating the foot is tricky due to motion not seen clearly by the naked eye, in which case a slow-motion camera may be necessary to ascertain true foot movement. This need is rare, however, and usually not found in recreational runners due to their relatively low training volume and velocity. Finally, biomechanics can change. What was once corrected may no longer be a problem, and new problems may arise.

HISTORY OF 20TH-CENTURY RUNNING SHOES

The history of the running shoe in the 20th century begins with Spalding's introduction of the long-distance running shoe. The company outfitted the 1908 U.S. Olympic marathon team in its models, and, based on observations of the shoes' performance, created a line of marathon shoes in 1909. It provided both high-top and low-top shoes with a pure gum sole and leather uppers that were "full finished inside so as not to hurt the feet in a long race." Within five years, the gum rubber sole had been replaced by the leather sole, and the research and marketing of running shoes had begun in earnest, though it would proceed in fits and starts.

Although Spalding continued to tinker with its running shoe models, the intrigue associated with running shoes that was sparked by the 1908 Olympic marathon gave way to a fascination with track spikes, particularly those manufactured by the Dassler brothers of Germany. Worn by Jesse Owens in the Munich Olympics, the spiked shoes were little more than a soft leather upper sewn to hard leather soles with permanent "nails" built into the soles in order to provide traction on dirt tracks.

Interest in the production of running shoes was rekindled in the United States in the mid-1960s through the mid-1970s, which ushered in the era of the running specialty business. Facing competition from the Japanese-imported Tiger running shoes, other companies, including Hyde, New Balance, and Nike, all began production of serious running shoes. The new shoes featured a higher heel, midsole cushioning material, and nylon uppers. In some cases, the shoes were well made; more often, they were not. In the late 1970s, however, *Runner's World* magazine began performing lab tests on running shoes, which forced manufacturers to either improve the quality of their shoes or lose market share. This change in the mind-set of the companies initiated a period of intense competition (which continues today) to provide the best fit with the most cushioning, stability, and durability in a shoe that also looks good (currently, the most authentic, extensive shoe review is the Solereview, www.solereview.com).

COMPONENTS OF RUNNING SHOES

When choosing a running shoe, emphasis should be placed on finding the right shoe in terms of both biomechanics and fit; one without the other can lead to injury. Remember, too, that a high price does not ensure success. For one runner, an expensive shoe may only deplete the bank account without aiding performance; for another, the same shoe may be expensive but perfect. The right choice depends on your foot type, shape, and biomechanics.

Upper

The upper of a running shoe (figure 11.1) consists of the material that covers the top and sides of the foot. It can be made either of multiple pieces of fabric sewn or glue-welded together or of a single seamless piece of material. All current running shoes are made of synthetic materials (nylons) for breathability, comfort, and weight reduction. Leather is no longer used because of its weight, cost, lack of breathability, and nonconforming shape after repeated use.

The front of the upper is referred to as the *toe box* (figure 11.2). It takes its shape from the shoe last (the form on which the shoe is built), but its style is determined by the shoe designer to meet the needs of the shoe wearer. The toe boxes of many shoes built recently are wider and deeper than in the past to

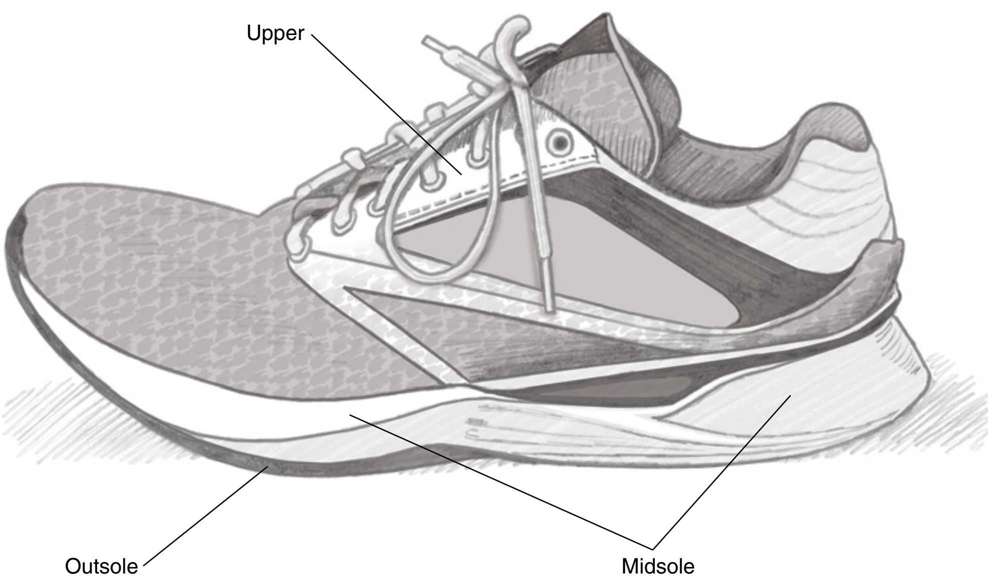


FIGURE 11.1 Lateral view of a shoe: upper, midsole, and outsole.

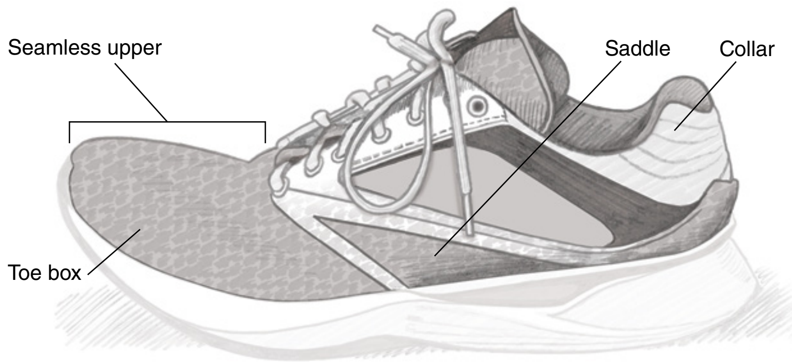


FIGURE 11.2 Upper.

accommodate the higher-volume (longer, wider, and larger) feet that have become more prevalent as the second running boom has brought more recreational runners with larger frames into the sport. The midfoot of the shoe's upper can be designed either in conjunction with or independently of the lacing system (e.g., ghillie lacing) to allow for various upper fits. Occasionally, companies try a nonsymmetrical lacing pattern that is ostensibly designed to improve the fit of the upper and prevent "hot spots" (pre-blister areas) from developing on the foot.

The design of a shoe's upper determines the shoe's fit, not in the sense of length but in terms of how the shoe envelops the foot. This factor is important because if the fit is improper, then the runner's biomechanical needs may go unmet. Only when the fit is spot-on can the shoe function as designed in terms of stability, motion control, and cushioning. For example, if the upper is too baggy in the midfoot, then excessive pronation can occur despite the presence of a medial support. In other words, the lack of proper fit may render the stability device ineffective in combating the pronation that it was designed to limit. In this way, injury can occur—in this case, tibia pain—even if a runner wears a shoe that is designed for his or her foot type.

This scenario often leads to disenchantment when purchasing shoes because of the confusion that results from following suggestions and guidelines yet still not getting relief from pain. With that in mind, here is a general guideline for purchasing shoes: If the shoe doesn't fit your foot well, then it isn't the best shoe for you, regardless of whether its biomechanics match your foot type. For example, it could be argued that for a mild overpronator, a cushioned shoe that fits perfectly is more stable than a mild stability shoe that is too roomy.

In conjunction with proper fit, a heel counter embedded in the upper material ensures a secure, mildly stable ride (a shoe industry term to describe the feel of the shoe during the contact phase) when running. Heel counters (figure 11.3) are hard plastic devices that stabilize the rear foot, helping the foot through the normal cycle of heel strike, midfoot stance (avoiding excess pronation), forefoot supination (the outward rolling of the forefoot), and toe-off from the

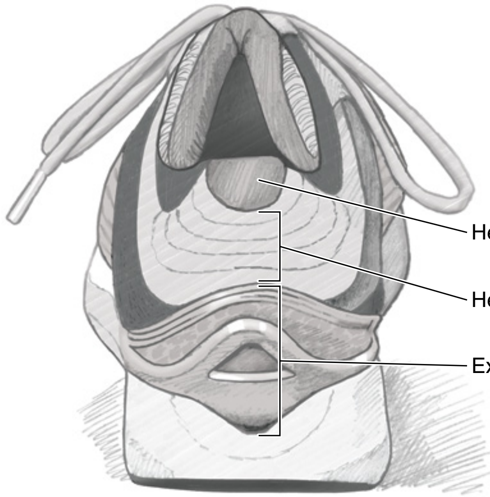


FIGURE 11.3 Heel counters and heel clefts.

smaller toes of the foot. Heel counters can be removed in shoes manufactured for underpronators, but doing so increases the possibility of Achilles tendinitis because of the increased movement of the calcaneus and the resultant pulling on the Achilles tendon.

Midsole

The midsole of a running shoe (figure 11.4) is made of EVA (ethylene-vinyl acetate) or rubberized EVA, which is used to cushion or stabilize the ride of the shoe during foot strike. Developed in the early 1970s as a cushioning material to rival polyurethane (which is denser and heavier), EVA has been combined with other proprietary cushioning materials (e.g., air and gel) and engineering designs (e.g., wave plates, footbridges, cantilevers, and truss systems) to minimize the impact shock generated during the foot strike and to guide the foot through its normal path.

Shoe manufacturers have long sought the holy grail of a material that would provide a moderately soft ride and the durability to withstand compression, which limits the life span of a shoe. Currently, a reasonable expectation for a running shoe's life is 350 to 500 miles (about 560 to 800 km). The development of a midsole that could provide, say, 750 miles (about 1,200 km) of consistently comfortable running would be a boon both to runners and to the manufacturing company that patented the material.

The current crop of rubberized midsoles provide dramatically better cushioning than their "sheet" EVA predecessors from the 1970s, but production of the material comes with an environmental cost. Specifically, traditional EVA midsoles take about 1,000 years to biodegrade entirely. Some running shoe manufacturers

FIGURE 11.4 Midsole.

are marketing certain midsoles as "green" (eco-friendly) because they degrade 50 times faster in a traditional landfill environment.

Although most runners look at the outsole to determine whether a shoe needs to be replaced, the question really revolves around the midsole. In fact, by the time the outsole of a running shoe has worn away enough to show significant wear, the midsole's ability to provide cushioning has long been compromised. Because midsoles provide cushioning, they also absorb and dampen the shock of impact. During a typical 30-minute run, that impact is felt some 2,700 times. If you multiply that figure by the impact force of three to four times the runner's body weight, it's amazing that a wedge of EVA only 2 inches (5 cm) thick can withstand about 150 of these training runs before being replaced.

The midsole is the part of the shoe that contains the various stability devices designed to prevent pronation. These devices are always placed on the medial side of the shoe, usually between the arch and the heel, because that location is close to the subtalar joint, which is the main controller of pronation. Occasionally, a shoe is produced with forefoot posting (to prevent late-stage pronation of the forefoot), but this design is nontraditional. Posting is never done on the lateral side of the shoe because it is unnecessary for underpronators (since a cushioned shoe allows the foot to pronate as needed) and counterproductive for pronators (for whom increasing the rate and degree of pronation leads to increased tibial discomfort).

For some time, shoe manufacturers have thought that the holy grail of midsole materials would be one that combined the relatively soft, comfortable ride of EVA with the resilience and durability of polyurethane (the older material that had fallen out of favor). Recently, Adidas has hit the sweet spot of these two materials with its patented Boost material, which is incorporated into all of the company's performance running shoes. In response, competing companies have scrambled to find their own proprietary blends to achieve the desired mix of responsiveness and durability. This situation offers a perfect example of how the consumer wins when competition raises the bar.

Outsole

The outsole of the running shoe (figure 11.5) has evolved dramatically from the gum rubber of the 1908 Spalding marathon trainers. The outsole (the part of the shoe that touches the road) is made of carbon and blown-rubber composites and provides a durable yet appropriately flexible ride. Because most runners strike with the lateral heel, manufacturers place the most durable carbon rubber in this part of the shoe to ensure longevity of the outsole. Despite the added durability of the carbon rubber, excessive wear still appears in this part of the shoe for most runners. This wear pattern is to be expected and does not indicate a proclivity toward overpronation or underpronation; it simply means that the runner is a heel striker.

If the outsole is completely worn through in the forefoot of the shoe, then the midsole cushioning was compromised long before, and the shoe is worthless as a shock absorber. Because the outsole of the shoe lasts much longer than the midsole cushioning, it is ineffective to use outsole wear as a guide for determining when to replace your running shoes. The best method of determining the life of a shoe requires little work. Simply pay attention to the mileage on your shoes by keeping a log or quick estimation of distance covered per week multiplied by weeks of training. After about 350 miles (about 560 km), replace your shoes when you begin to have aches or pains in your legs that you did not have before. In contrast, if a shoe model is not correct for a runner's biomechanics, weight, flexibility, or foot shape (the factors that determine the best shoe), then

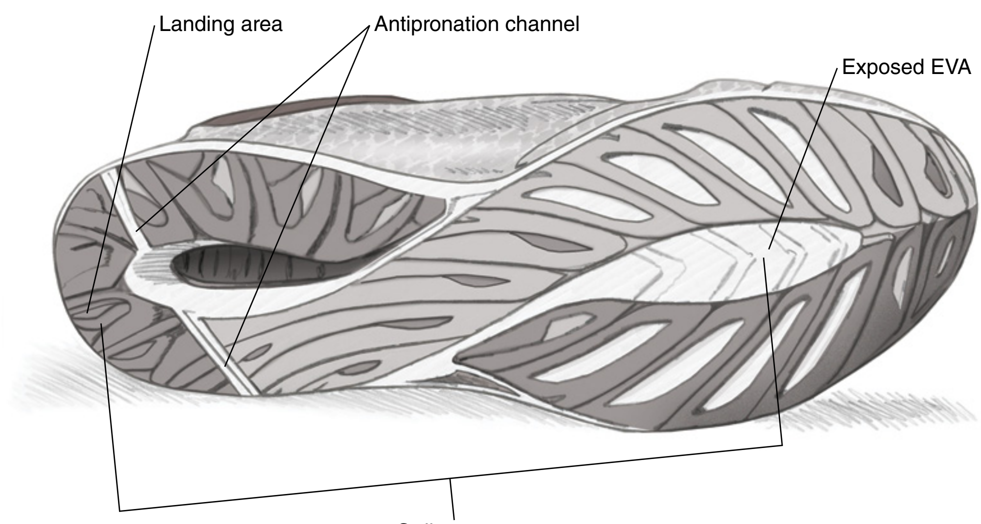


FIGURE 11.5 Outsole.

discomfort or injury occurs within the first 100 miles (160 km) of running. Thus, the wrong shoe should rarely be confused with a shoe that is merely worn out.

Shoe manufacturers continuously alter the strike paths of their shoes' outsoles and the surface patterns of the rubber to improve comfort and durability. Although these aims seem to be worthwhile, the role of aesthetics in shoe design cannot be ignored. At every phase of design and development, the aesthetics of the shoe—its attractiveness to consumers—must be weighed against the practicality of building the shoe and its effectiveness for running. Often, the aesthetics take precedence, and a much-hyped shoe proves to be a performance dud—albeit one with an expensive advertising campaign.

Insoles and Orthotics

Runners want to wear comfortable shoes that help prevent injuries; however, because running shoes are not custom made, there will always be a bit of a compromise when it comes to fit. Because each runner's feet are unique (and not even symmetrical with each other), accommodations are often needed in order to enhance a running shoe's fit and function. For this purpose, runners turn to insoles and orthotics.

Each pair of running shoes comes with an insole made of EVA or another material combined with EVA to add comfort (shock absorption) and to facilitate the fit. The insole costs less than 50 cents to manufacture, and it is mostly useless. It is also removable, and for good reason: Most runners replace it with a more cushioned or more stable insole that bears some resemblance to the shape of the human foot. In fact, in the past decade, over-the-counter replacement insoles have become a serious revenue generator for running specialty stores. The proliferation of such stores has created more retail outlets for insoles, and insole manufacturers have responded by producing good-quality products for less than $30.

It may seem redundant to spend $100 on a pair of shoes and $30 on a pair of specialized, over the counter insoles when you could just buy a $130 pair of running shoes to begin with. The true value of the insole, however, lies in its ability to customize the shoe to the runner's foot. Thus, the $100 shoe with the $30 specialized insole feels closer to a perfect fit than the $130 shoe does because it more closely resembles a shoe made from a mold of the runner's own foot. Moreover, the semi-custom insoles not only aid fit but also helps correct for poor biomechanics. For instance, an insole can be posted to compensate for pronation factors or high-arched to help prevent plantar fasciitis.

Although these over the counter insoles work well, they are not for every runner. Many runners can do without special insoles because they do not have major biomechanical problems that will be exacerbated by training. Insoles are a viable option, however, for runners who have run a lot of miles, are training at a high volume, or have chronic injuries.

For those who do not find relief with a specialized over-the-counter insole, the next step is to visit an expert (i.e., a podiatrist or certified pedorthist) to obtain custom-made orthotics. An orthotic device is meant to correct an anatomical or biomechanical abnormality. In theory, it realigns the foot strike in order to alleviate any imbalance or weakness involved in the kinetic chain of events initiated by running. Do orthotics work? Sometimes!

When visiting a podiatrist or certified pedorthist, a runner should expect to go through the following process before an orthotic device is produced. First, the specialist should take a thorough history of running injuries, shoes worn, and remedies attempted. Next, the specialist should take measurements of leg length and evaluate joint mobility; X-rays may also be taken but are often unnecessary. After evaluating the feet, the specialist will make plaster molds of them by placing each foot in a neutral position and wrapping plaster-soaked strips of gauze around it.

The most important step is that of placing the foot in the neutral position. Because the goal of an orthotic is to correct, the foot must be in the neutral position so that the cast shows any corrections to be made. The needed correction is indicated by the difference between the runner's foot and the appropriate position of a runner's foot in neutral position. When the cast is sent to an orthotics lab to produce the orthotic, a technician evaluates the cast and takes more measurements. From the "negative" cast, a "positive" model is created from plaster and ground to the specifications provided by the doctor.

A hard orthotic is fabricated from thermoplastic and filled with cushioning material. It is posted medially no more than 4 degrees to help position the foot in neutral at midstance. It is covered by a thin layer of synthetic material. In contrast, a soft orthotic, also referred to as an accommodative orthotic, is more of a custom-made arch support than a posted orthotic. It is intended not so much to provide medial stabilization for pronation as to provide arch support for a runner with high, rigid arches.

A running orthotic typically extends full length and replaces the insole of the shoe. It is common, however, for a laboratory to offer a three-quarter-length orthotic. Because most rear-foot motion issues can be alleviated with a three-quarter-length orthotic, logic would seem to dictate that the inherent weight savings would be welcome. Unfortunately, the lack of a continuous surface under part of the foot leads runners to fabricate their own system for completing the orthotic. For this reason, it is best to purchase an orthotic with a full-length cover.

The standard for a well-constructed orthotic is twofold: Does it fit comfortably into a running shoe (even if that shoe is different and larger than the one you were previously wearing), and does it eliminate the targeted running injuries without causing other injuries? Both answers should be a resounding yes! If not, contact your doctor for a follow-up appointment to reevaluate the orthotic.

The process of pairing an orthotic device with a running shoe involves a combination of art and science. If a hard, corrective orthotic is worn, then a neutral cushioned shoe that encompasses the orthotic well and provides a good fit may suffice to eliminate any overpronation injuries. If a stability shoe is still needed even with a hard, corrective orthotic, then take care to avoid the possibility of overposting the foot. The marriage of a stability shoe and a corrective orthotic is a possible recipe for iliotibial band syndrome—an injury usually associated with underpronators who stay on the lateral aspect of their foot through the foot strike, which creates tightness in all of the muscles and soft tissue laterally from the foot to the hip. At the first sign of pain on the lateral side of the knee or tightness in the hip area, reconsider the combination of a stability shoe and corrective orthotic.

Underpronators who wear accommodative orthotics should continue to wear cushioned shoes. The only caveat—and this is true for overpronators with orthotics as well—is that an extra half size may be needed in order to fit the orthotic into the running shoe. The orthotic replaces the insole that comes with the shoe, but it is higher in volume and thus needs to be fitted properly so that the biomechanics it is meant to promote during running can proceed seamlessly.

The ultimate goal of a well-designed and well-constructed running shoe or orthotic device is to promote comfortable, injury-free running. This goal is the reason for features such as extra cushioning that reduces impact forces, stability devices that add medial posting to limit pronation generated by the subtalar joint, and EVA densities that ease the transition from heel strike to midstance. In fact, all leg and foot injuries should be eliminated by combining appropriate footwear and orthotic devices (matched with a runner's biomechanical needs) with the strength training program for the lower leg and foot presented in chapters 4 and 5.

One caveat is that running shoes and orthotics must be appropriate to the feet that wear them and must be replaced when the cushioning, stability, or accommodative properties are compromised. Typically, a running shoe should last at least 350 miles (560 km), an aftermarket insole should last through every other shoe purchase, and a custom orthotic should last at least two years (although the cover may need to be replaced). Trained employees at running specialty stores can help runners match running shoes with appropriate foot types and match feet with nonprescription insoles which provide protection similar to that offered by orthotic devices but are not custom-made.

The effectiveness of any running shoe or orthotic device hinges not just on biomechanics but also on fit. A well-constructed shoe that is biomechanically correct for a runner may not function correctly if it is ill-fitted to the foot. When purchasing a shoe, make sure that the shoe is neither too long nor too short and neither too wide nor too narrow. Since feet tend to swell during the day due to gravity, it is advisable to try on shoes later in the day rather than earlier. Also, try the new shoes with the orthotic device to be worn in order to replicate the fit of the shoe-and-insert combination. If it doesn't work in the store, it's not going to work on the road, trail, or track!

TECHNOLOGY

Technology has infiltrated most vocations and avocations in our lives, and running is no exception. In a sport that has often been recommended for its simplicity—all you need are shoes, shorts, and, for women, a sport bra or

Barefoot Running

Barefoot running could have been included in chapter 4 in the list of exercises to strengthen the foot because that is what it does best (along with developing some proprioceptive awareness). Even so, daily barefoot training is not a viable substitute for running in shoes. It would be painful, to say the least, given that most runners log the majority of their miles on asphalt, concrete, treadmills, and gravel-strewn trails. Granted, the argument has been made that many African runners have trained barefoot and enjoyed considerable success (for a famous example, consider South African native Zola Budd). The counterargument is that all of the world records are held by shoe-wearing runners.

In any case, much like the strength training exercises outlined in chapters 4 through 8, running without shoes has many practical applications when used as a supplement to running training. Proponents of barefoot running tout the muscular strength gained by doing it, which is an accurate assessment when viewed in the proper context. Advocates also argue for the psychological release purportedly derived from running on sand or lush grass (which may also relate to the fact that these surfaces are typically found in places more likely to be idyllic), although such an effect would seem only tenuously connected to performance enhancement.

The best reason to do some barefoot running on healthy grass or hard-packed sand—not more than twice a week and no more than 100 meters straight for a total of 400 meters per session in the beginning—is to train the muscles of your feet to work differently than they do when running shoes are worn. Barefoot running forces the feet to work in ways that prevent atrophy in muscles that otherwise function in the same way during every run performed in running shoes (with or without orthotics). In addition, an antiorthotic movement in running espouses mixing in some barefoot running, and running in neutral shoes for overpronators, in order to force the foot to strengthen itself and thus prevent injury. Just as the exercises presented in this book detail how to strengthen your body to improve running performance, barefoot running can help strengthen your feet to withstand the countless training miles required of them. As with all strength training, however, if you feel pain while running barefoot, then you should stop.

Overall, however, almost 10 years after the writing of this book's first edition, the whole minimalist movement has become a footnote in running training. The pendulum has swung, and "max" cushioning shoes such as the Hoka models are now leading the way; this is also the main appeal of the Boost material discussed earlier in this chapter. Although minimalist shoes still have their place in some runners' closets, that group has proven to be a vocal minority. In addition, Vibram, the company that benefitted most from the hype associated with minimalist running shoes—which was sparked by the book *Born to Run* by Christopher McDougall (New York: Knopf, 2009)—settled a class-action lawsuit by acknowledging that it had made false and unsubstantiated claims about the health benefits of its glove-like footwear.

Most current studies on barefoot running are clear about one point: It is not the panacea for injury prevention that it was once touted to be. It may work, to some degree, for some runners, but it is not applicable for all runners. Ultimately, thoughtful trial and error is the best method for understanding the complexities of biomechanics and shoe construction.

top—technological advances have added heart-rate monitors, GPS watches, and sunglasses with built-in MP3 players. One of the most recent developments is a new breed of tracking device (a “pod”) that measures power and provides data such as ground-contact time, impact shock, and symmetry (thus enabling independent analysis of movement on each side of the body).

As with other kinds of technology that generate data, these options for runners can be a bit overwhelming. Which kinds of information are beneficial, and which are just data? At what point, if any, does the flood of data paralyze rather than inform one’s training? For example, does a simple 50-minute run on a favorite trail need to be GPS-mapped and uploaded to an app (e.g., Strava) when it is a staple of weekly training? What if the pace begins to increase without a corresponding increase in heart rate? What if the heart rate also increases? What if pronation of the left foot increases as the pace quickens? All of this is good data, and can be used to tailor workouts and shoe choices. It can also lead to data overload and ruin a simple training run!

Running Sensors

If you like data, then a running sensor may be just the right tool to focus your training. Running sensors use accelerometers, which measure acceleration relative to free fall. Essentially, they measure the runner’s movement, whether forward (distance) or up and down (impact). Some sensors also purport to measure blood oxygen saturation via a sensor on the calf. Running sensors can serve as interesting tools when evaluating running shoe options. A foot pod, which notes impact, pronation, and braking, offers a highly effective means for evaluating shoe options and determining whether your current shoe is working to aid your running. This information can also help you make good decisions about training methodology; the same is true for sensors that measure distance, pace, and power.

Power Meters

About 15 years ago, power meters began to influence how cyclists trained and raced; more recently, they began to enter the world of running. Power meters are meant to document and normalize effort. For instance, you know that hilly courses and windy days affect pace and heart rate (metrics for determining effort), but how can you compare that effort with the effort required to complete the same run in different conditions or with different types of training runs? In other words, how do you compare the runs in an apples-to-apples manner?

In light of these questions, power meters have many applications for training and racing. For the purpose of analysis, they remove the variables of course profile, wind, and the effects on heart rate by creating one standard of effort that can be used to compare workouts performed in different conditions. Thus they enable you to obtain useful data for training and racing instead of disconnected data.

The market for power meters is currently dominated by a few models. Each uses a pod-shaped receiver that clips on your shoes and feeds data into a watch or phone. The data collected can be viewed in an app or uploaded onto a third-party site (such as TrainingPeaks) that has software in place to read it. These devices provide normalized data by expressing the effort required to complete a workout in terms of wattage. The data can be further refined in the form of watts per kilogram to provide a basis of comparison with another runner's data or with new data for the same runner after a weight loss or gain.

How can this information help you become a better runner? Instead of guessing whether your run yesterday was hard or moderately easy—in other words, relying on a subjective understanding that may not accurately depict what your body experienced—the power meter gives you an objective number to compare with your baseline (derived via field tests). For example, say that runner A usually runs 5 miles (8 km) at a pace of 8:00 per mile with 135 beats per minute (bpm) but has just run that distance in a wind of 12 miles per hour at 8:15 per mile with 142 bpm. Will that workout be more or less difficult to recover from? Using a power meter, the data would be one number (say, 185 watts) for the first run and another number (say, 195 watts, or 165 watts) for the second run. Thus the power meter gives you one metric to understand. Once wattage limits are established for a given athlete, heart rate becomes a secondary factor, as does pace per mile or kilometer, because wattage becomes the only data needed to establish training and racing guidelines.

Let's consider another scenario, this one comparing a hilly 6-mile (9.7 km) run with a flat 3-mile (4.8 km) tempo run at lactate threshold pace. What pace do you need to run in the hills in order to equal the effort required by the tempo run? Do you need to do more hill work in order to get the same value? Do you want the same value?

These kinds of data give an athlete a way to perform workouts in various places without needing to know the nuances of the terrain. Running for one hour at an average of 240 watts is the same in any country on any terrain in any conditions. That is not the case with pace and heart rate.

Other metrics provided by these new devices include contact time, pronation rate, and foot-strike impact—all of which can be used to aid performance and avoid injury. Essentially, then, these devices provide data that were previously available only through the use of force plates in biomechanical assessment labs at universities, and they do it at a fraction of the price. Thus a layperson now has access to raw scientific data to help improve running.

As with choosing footwear (or going barefoot), the amount and quality of data you choose to parse needs to be established via thoughtful trial and error, and the equilibrium point will fluctuate. Again, try to be an experiment of one and enjoy the places you go while finding your running self. The use of a power meter takes us to a reality most likely not envisioned by runners even 30 short years ago. It supposes a future in which running becomes almost totally objective and seems to leave little room for the human element. What, ultimately, will this new frontier mean for the sport of running?

THE FUTURE OF RUNNING

Clearly, running is here to stay. As the basis on which countless other sports depend, running will always be needed, both as part of basic training and as a sport skill. Many people have wondered if and when world-record progression will cease, and it is worth trying to calculate whether or where a limit might be reached. For instance, Usain Bolt's world-record time for the 100-meter dash is 9.58 seconds. If we translate that pace to a distance of 1,500 meters, we get a time of 2:23—more than a minute faster than the current world record held by Hicham El Guerrouj (though, tellingly, that record is nearly 20 years old; record progression is slowing). Apparently, then, the ultimate 1500-meter record that is possible might lie between those two times, unless of course a "super" Bolt arises to lower the 100-meter record still further—a progression that has already occurred, of course, with all running records leading up to the current ones!

Ultimately, speed is multifactorial. While it may seem to depend on the runner's anatomy and physiology, it may also hinge on his or her psychology, quality of training, and ability to tolerate fatigue; the meteorological and race conditions; the athletes against whom the runner competes; the running surface; and the runner's footwear and other gear. For the "perfect" run to occur, all of these factors would need to align perfectly, which is about as unlikely as winning a lottery!

Taking each of these factors in turn, the athlete's training would have to be brought to a peak on the day of the run, so that the athlete is neither overtrained nor undertrained. In addition, the ambient temperature would need to be warm enough to prevent muscles and joints from chilling but not so warm as to fatigue the athlete. Any wind would probably be counterproductive unless a slight chill would help keep the core body temperature stable. The mental approach would be all-important. Any doubt in the runner's mind would depress the body chemicals that provide drive and reduce the runner's ability to overcome the pain that accompanies running flat out for longer than the body can normally tolerate. The runner would also need to maintain a constant pace, since doing so is the most efficient, and therefore the least tiring, way to run.

Human anatomy is changing as the human race develops. Many of us are better fed than our predecessors were, and growth is less likely to be interrupted by malnutrition or illness. On the downside, as technology improves, we have less immediate need to exercise. Even children, who are often ferried to school, now run the risk of obesity through lack of exercise—a plague that is causing more and more people to suffer with diabetes and circulatory problems. At the moment, the world's fastest middle-distance runners all come from East Africa, where many children run a total of 20 miles (32 km) per day going to and from school. Naturally, this routine causes them to develop stamina. If advances in travel stop this daily running, will these humans still be the world's preeminent runners? Will races be run, and won, in slower times than they are now?

Most of the world's best athletes already train both efficiently and to the maximum limit allowed by their anatomy and physiology; their efforts are aided by frequent laboratory testing. Thus they train far harder than their forebears did, and any further increase in either quality or quantity is liable to be fraught with risk. Overtraining leaves athletes vulnerable to injury and all the psychological strain and loss of fitness that accompanies it; it may also be detrimental to any attempt to run faster.

Advances in genetic engineering could mean that, at some point, our descendants will have prenatal testing and treatment that frees them from the potential for illness. To a certain extent, this already happens through the prevention of many birth defects. If we extrapolate this scenario, it is not hard to envision scientists being able to ensure that the progeny of the fastest athletes inherit only those genes that help them run faster than their parents. A couple of generations on, these offspring may have such an artificial genetic makeup that they feel no pain from lactic acid buildup or from their heart beating at its maximum rate for a longer period of time than is nowadays accepted. They may even be programmed to use less oxygen. As fantastic as it may sound, we are approaching a time in which scientific knowledge makes these changes not only possible but probable.

The current dominance exhibited in running by East Africans is such that practically no other runner currently has a meaningful chance of beating them. But why could not genetic engineering ultimately produce a human robot that carries all before it? Cynical observers may say that this question enters the world of science fiction, but never say never. Every day, evolution brings subtle changes to our lives, and this scenario does not live beyond the realm of possibility.

So, the future of running hinges on two factors: speed and need. How fast can humans run? And will it be necessary to run (and if so, to what end)? We believe that runners will get faster, but ever more slowly, and that whether or not humans need to run, they will desire to do so. Only time will tell if we are correct.

EXERCISE FINDER

FEET AND ANKLES

LEGS

CORE

SHOULDERS AND ARMS

CHEST AND BACK

INJURY PREVENTION

ABOUT THE AUTHORS


Courtesy of Carlos Schultz.

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Patrick Milroy has been the chief medical officer for the Road Runners Club in Great Britain since 1998. From 1991 to 2007, he was a medical advisor and contributor to *Runner's World*, and for 10 years before he was similarly involved with its precursors, *Jogging* magazine and *Running* magazine.

Dr. Milroy received the award of fellow from the Institute of Sports Medicine in 1999 and from the UK Faculty of Sport and Exercise Medicine in 2006. He has served as a medical officer for many athletic events—including the World Half Marathon Championships, Team England Commonwealth Games (four times), and British Athletics Federation—and was medical officer for the Great Britain team at the World Junior Championships (three times) and European Junior Championships (two times).

Dr. Milroy is the author of *Sports Injuries*, coauthor of the *AAA Runner's Guide*, and author of numerous other articles on sport and exercise topics for journals, magazines, and newspapers. He is also an accomplished runner: winner of the World Medical Games 5,000 meters event and half marathon in 1980, 1982, and 1984 and winner of the European Medical Games 20K, 5K, and 1,500 meters events in 1983. His personal best in the marathon is 2 hours and 26 minutes. At the age of 65, he cycled from Los Angeles to Boston (3,300 miles) in 35 days.

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