SWIMMING Anatomy

IAN MCLEOD

Your illustrated guide for swimming strength, speed, and endurance

SWIMMING ANATOMY

Ian McLeod

Human Kinetics

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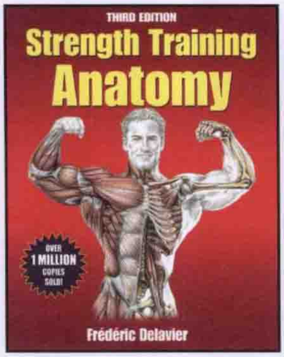

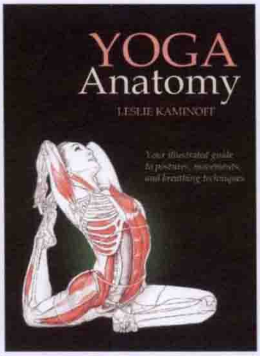

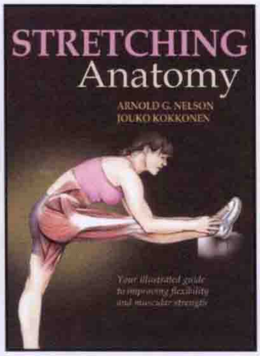

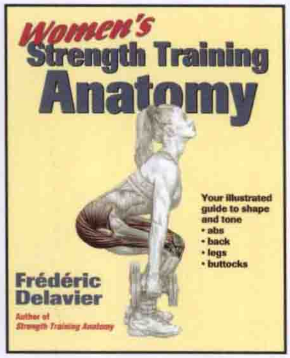

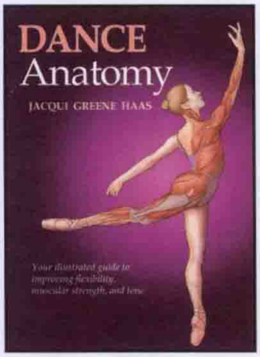

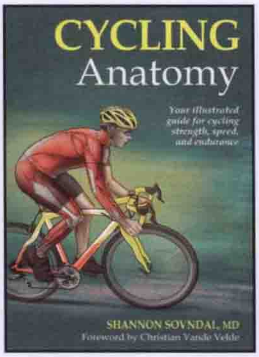

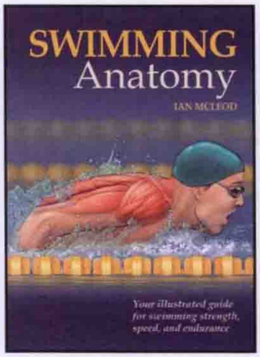

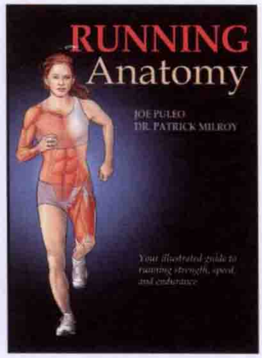

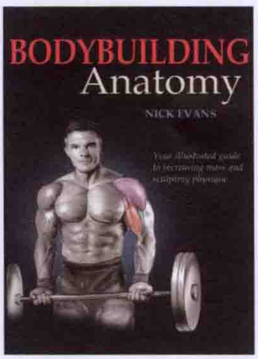

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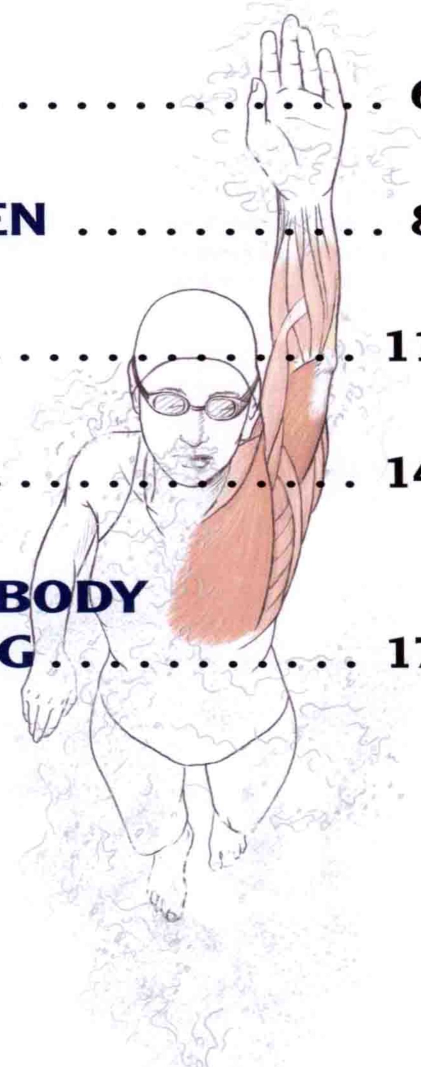


CHAPTER 1 THE SWIMMER IN MOTION

Swimming Anatomy is both a visual guide to the role of the musculoskeletal system in the four competitive swim strokes and a catalog of swimming-oriented dryland and weight-room exercises. The exercises in the text will help you maximize your performance and gain a competitive edge. Specific examples will help you choose exercises that target the most-used muscles for each stroke, starts, and turns to ensure that you are getting the best results from your program. Included are exercises that may help you prevent injuries by strengthening key stabilizing muscles and decreasing muscle imbalances. To help you understand how these exercises enhance performance, descriptions of the roles that various muscles play in propelling a swimmer through the water and guidance in using selected exercises to target those muscles are included. This chapter features an overview of the primary muscles used in the kicking motions and during the pull-through and recovery phases of freestyle, butterfly, backstroke, and breaststroke. The chapter also addresses some strength and conditioning principles and how they relate to designing a swimming-specific dryland program. Chapters 2 through 8, organized according to major body parts, each contain exercises with accompanying illustrations and easy-to-follow descriptions and instructions. The anatomical illustrations that accompany the exercises are color-coded to indicate the primary and secondary muscles and connective tissues featured in each exercise and swimming-specific movement.

Primary muscles | Secondary muscles | Connective tissues

Swimmers face several unique challenges that athletes in most land-based sports do not encounter. The first challenge is the total-body nature of all four competitive strokes, which involve movements of both the upper and lower extremities. A coordinated effort of the musculoskeletal system is required to keep each body part moving correctly to maximize efficiency of movement through the water. To visualize this coordinated effort, think of the body as a long chain and each body segment as a link in the chain. Because all the segments are linked together, movement in one segment affects all the other segments. This linkage, commonly referred to as the kinetic chain, allows the power generated by the arms to be transferred through the torso to the legs. But if a link in the chain is weak, a loss of power transfer can occur, bodily movements can become uncoordinated, and the risk of injury can increase.

Another unique demand of swimming is that swimmers are required to create their own base of support. Unlike land-based athletes, who have a stable surface to push off from, you have to generate your own base of support, because most training takes place in a fluid environment. The key to linking the movement of the upper and lower extremities in the water, and at the same time generating a firm base of support, is a strong and stable core. The core is best thought of as the foundation on which the muscles of the upper and lower body are built. Even a strong and well-designed house will eventually deteriorate if the foundation is weak.

Without a doubt, swimming itself is the most effective way to become a better and faster swimmer, but several components outside the water play an important role in how you develop as a swimmer. One of those is a well-designed dryland program based on an appreciation of the relationship between the body's muscular framework and stroke mechanics. While engaged in swimming, muscles primarily function as either the mover of a body segment or a stabilizer of a body segment. An example of a muscle functioning as a mover is the latissimus dorsi, commonly known as the lats, moving the arm through the water during the propulsive phase of all four competitive strokes. The near-constant activity of the core abdominal musculature is a prime example of a group of muscles functioning as a stabilizing mechanism. Both functions are vital to proper stroke mechanics and efficient movement through the water. Descriptions of the muscle recruitment patterns for each of the four strokes are categorized as those that are active during the propulsive phase, the recovery phase, and kicking.

Throughout the exercise descriptions in the subsequent chapters you will see a series of five icons, one for each of the strokes and one for starts and turns. The purpose of these icons is to identify the exercises that are particularly well suited to a specific stroke or starts and turns.

freestyle

backstroke

breaststroke

butterfly

starts and turns

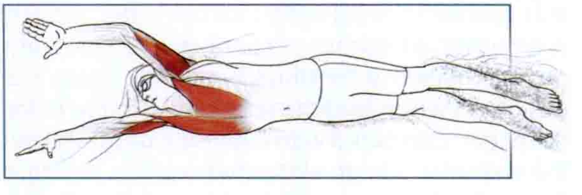
Freestyle

As the hand enters into the water, the wrist and elbow follow and the arm is extended to the starting position of the propulsive phase. Upward rotation of the shoulder blade allows the swimmer to reach an elongated position in the water. From this elongated position, the first part of the propulsive phase begins with the catch. The initial movements are first generated by the clavicular portion of the pectoralis major. The latissimus dorsi quickly joins in to assist the pectoralis major. These two muscles generate a majority of the force during the underwater pull, mostly during the second half of the pull. The wrist flexors act to hold the wrist in a position of slight flexion for the entire duration of the propulsive phase. At the elbow, the elbow flexors (biceps brachii and brachialis) begin to contract at the start of the catch phase, gradually taking the elbow from full extension into approximately 30 degrees of flexion. During the final portion of the propulsive phase the triceps brachii acts to extend the elbow, which brings the hand backward and upward toward the surface of the water, thus ending the propulsive phase. The total amount of extension taking place depends on your specific stroke mechanics and the point at which you initiate your recovery. The deltoid and rotator cuff (supraspinatus, infraspinatus, teres minor, and subscapularis) are the primary muscles active during the recovery phase, functioning to bring the arm and hand out of the water near the hips and return them to an overhead position for reentry into the water. The arm movements during freestyle are reciprocal in nature, meaning that while one arm is engaged in propulsion, the other is in the recovery process.

Several muscle groups function as stabilizers during both the propulsive phase and the recovery phase. One of the key groups is the shoulder blade stabilizers (pectoralis minor, rhomboid, levator scapula, middle and lower trapezius, and the serratus anterior), which as the name implies serve to anchor or stabilize the shoulder blade. Proper functioning of this muscle group is important because all the propulsive forces generated by the arm and hand rely on the scapula's having a firm base of support. Additionally, the shoulder blade stabilizers work with the deltoid and rotator cuff to reposition the arm during the recovery phase. The core stabilizers (transversus abdominis, rectus abdominis, internal oblique, external oblique, and erector spinae) are also integral to efficient stroke mechanics because they serve as a link between the movements of the upper and lower extremities. This link is central to coordination of the body roll that takes place during freestyle swimming.

Like the arm movements, the kicking movements can be categorized as a propulsive phase and a recovery phase; these are also referred to as the downbeat and the upbeat. The propulsive phase (downbeat) begins at the hips by activation of the iliopsoas and rectus femoris muscles. The rectus femoris also initiates extension of the knee, which follows shortly after hip flexion begins. The quadriceps (vastus lateralis, vastus intermedius, and vastus medialis) join the rectus femoris to help generate more forceful extension of the knee. Like the propulsive phase, the recovery phase starts at the hips with contraction of the gluteal muscles (primarily gluteus maximus and medius) and is quickly followed by contraction of the hamstrings (biceps femoris, semitendinosus, and semimembranosus). Both muscle groups function as hip extensors. Throughout the entire kicking motion the foot is maintained in a plantarflexed position secondary to activation of the gastrocnemius and soleus and pressure exerted by the water during the downbeat portion of the kick.

Butterfly

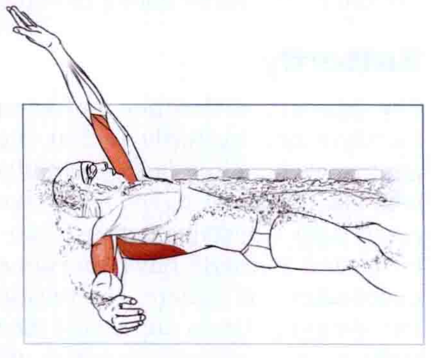


The primary difference between freestyle and butterfly is that the arms move in unison during butterfly whereas reciprocal movements take place with freestyle. Because butterfly and freestyle have the same underwater pull pattern, the muscle recruitment patterns are almost identical. As with freestyle, the swimmer's arms in butterfly are in an elongated position when they initiate the propulsive underwater portion of the stroke. Muscles active during the entire propulsive phase are the pectoralis major and latissimus dorsi, which function as the primary movers, and the wrist flexors, which act to maintain the wrist in a neutral to slightly flexed position. The biceps brachii and brachialis are active as the elbow moves from being fully extended at the initiation of the catch to approximately 40 degrees of flexion during the midpart of the pull. Unlike in freestyle, a forceful extension of the elbow is emphasized during the final portion of the pull, resulting in greater demands being placed on the triceps brachii. As in the freestyle stroke, both the rotator cuff and deltoid are responsible for moving the arm during the recovery phase, but the mechanics are somewhat different. Butterfly lacks the body roll that aids the recovery process during freestyle; instead, an undulating movement of the torso occurs, which brings the entire upper torso out of the water to aid in the recovery process.

Again, the shoulder blade stabilizing muscles are extremely important, because they function to provide a firm anchor point for the propulsive forces generated by the arms and help reposition the arms during the recovery phase of the stroke. Although butterfly lacks the body roll present in freestyle, the core stabilizers are still important in linking the movements of the upper and lower extremities and have an important role in creating the undulating motion that allows the swimmer to get the upper torso and arms out of the water during the recovery process. The undulating movement is initiated with contraction of the paraspinal muscles that run in multiple groups from the lower portion of the back to the base of the skull. This contraction results in an arching of the back, at which time the arms are moving through the recovery process. Contraction of the abdominal muscles quickly follows, which prepares the upper body to follow the entry of the hands into the water to initiate the propulsive phase of the stroke.

As with the arms, the muscles used in generating the kicking movements during the butterfly kick are identical to those used during the freestyle kick; the only difference in kick mechanics is that the legs move in unison. The propulsive downbeat begins with contraction of the iliopsoas and rectus femoris, acting as hip flexors. The rectus femoris also initiates knee extension, and associated firing of the quadriceps muscle group further aids in extension of the knee. The gluteal muscle group drives the recovery phase of the kick. Concomitant contraction of the hamstring muscles also works to extend the hip. The foot is maintained in a plantarflexed position through a combination of the resistance from the water and activation of the gastrocnemius and soleus, acting as plantarflexors. The dolphin kick that is used at the start of the race and off each turn wall recruits a larger group of muscles than the smaller, more isolated kick tied into the arm movements. Besides the movements generated at the hips and knee, the dolphin kick ties in the undulating movements of the torso through activation of the core stabilizers and the paraspinal musculature.

Backstroke



Although backstroke is unique in body positioning among the competitive strokes, the stroke phases can still be divided into a propulsive phase that consists of hand entry into the water, a catch component, a finishing component, and a recovery phase. Rotation at the shoulder puts the hands in a position in which the little finger is the first to enter the water. Combined with extension of the elbow, the swimmer is in an elongated position to begin the underwater propulsion phase of the stroke. A difference between backstroke and freestyle or butterfly is that the initial catch component is dominated by the latissimus dorsi. The pectoralis major makes a smaller contribution. Despite these differences the latissimus dorsi and the pectoralis major are still the prime movers and are active to some degree throughout the entire propulsive phase. Although the wrist flexors are still an integral part of the entire propulsion phase, the wrist is maintained in a neutral to slightly extended position. Through a combination of pressure forces from the water and activation of the biceps brachii and brachialis, the elbow transitions into approximately 45 degrees of flexion at the start of the catch. By the end of the catch the elbow may be flexed as much as 90 degrees just before transitioning into the finishing component. As with the finishing component in butterfly, more emphasis is placed on forceful extension of the elbow, placing high demand on the triceps brachii during the final portion of the propulsive phase.

The role of the stabilizing musculature during backstroke is similar to the role that it plays in freestyle, largely because of the similar reciprocal arm movement and the integration of body roll into both strokes.

The kicking motion seen in backstroke is a combination of movements that we have seen in freestyle and butterfly kicking mechanics. Like freestyle, backstroke uses reciprocal kicking movements. The major difference is that the position of the swimmer causes most of the force to be generated during the upbeat portion of the kick as opposed to the downbeat in freestyle. Backstroke also uses the dolphin kick off the start of a race and off each wall. The muscle recruitment patterns are the same in each case; the only change is in the direction because of the swimmer's body position.

Breaststroke

As with the other strokes the arm movements that take place during breaststroke are categorized as a propulsive phase and a recovery phase. The propulsive phase begins with the shoulders and arms in an elongated overhead position. The first half of the underwater pull is similar to that used in freestyle and butterfly. The clavicular portion of the pectoralis major starts the movement, and the latissimus dorsi quickly joins in. During the second half of the pull, forceful contractions of the pectoralis major and latissimus dorsi pull the arms and hands into the midline of the body to finish the pull. The forces generated during the final phase are directed toward forward propulsion of the swimmer in the water and upward propulsion of the swimmer's torso, which is aided by contraction of the paraspinal muscles. This movement brings the swimmer's head and shoulders out of the water. Flexion and rotation at the elbow bring the hands to the midline of the body and mark the conversion into the recovery phase. To return the hands to the starting position, the arms must be returned from their position under the chest. This motion is carried out by recruitment of the pectoralis major, anterior deltoid, and the long head of the biceps brachii, which all function to flex the shoulder joint. At the same time, extension of the elbow by the triceps brachii results in completion of the recovery phase, and the arms return to their extended and elongated position.

As with the other strokes, the shoulder blade stabilizing musculature is crucial to creating a firm base of support for the movements and forces generated by the arms. Like the butterfly stroke, the breaststroke lacks a body roll component. Even so, the core-stabilizing musculature is important in ensuring an efficient linkage between the movement patterns of the upper and lower extremities.

Like the arm movements, the kicking mechanics can be divided into a propulsive phase, consisting of outsweep and insweep components, and a recovery phase. The propulsive phase begins with the feet hip-width apart and the knees and hips in a flexed position. The outsweep is initiated with outward rotation of the feet, which is accomplished by a combination of movements at the hip, knee, and ankle. After the foot has been turned outward, the outer sweeping motion is continued by extension of the hip and knee. The gluteal musculature and the hamstrings function to extend the hip, and the rectus femoris and quadriceps act to straighten the knee. At the transition from the outsweep to the insweep, the knees and hip are still not completely extended, so the respective muscle groups continue their action into the insweep component until the knees and hip are fully extended. At the start of the insweep the legs are in an abducted position, generating an opportunity for force production through rapid adduction of the legs. The legs are brought back together by contraction of the adductor muscles that run along the upper portion of the inner thigh. To minimize drag during the final portion of the insweep, the calf muscles are activated to bring the foot and ankle into a pointed position. Recovery is accomplished by recruitment of the rectus femoris and iliopsoas, which serve to flex the hip, and recruitment of the hamstrings, which serve to flex the knee.

Dryland Training Programs

Although this book is not intended to give full program design details and guidelines, it does provide you with an understanding of how each exercise can directly benefit you as a swimmer, which in turn can help you make better decisions when choosing exercises for a specific program design. For example, if your program calls for an exercise that targets the triceps, you have many to choose from in chapter 2. We will, however, lay out some general principles and ideas for training programs here.

You should be aware of several considerations when designing a dryland program. The repetitive nature of swimming predisposes swimmers to developing muscle imbalances. Muscles such as the latissimus dorsi and pectoralis major become overdeveloped in relation to the smaller muscles that make up the scapular stabilizers (particularly the middle and lower trapezius and the rhomboids). In the lower extremity the quadriceps and hip flexors often become dominant over weaker hamstrings and gluteal muscles. These muscle imbalances not only lead to strength imbalances but also may create flexibility and postural imbalances that can predispose you to injury and inhibit optimal performance. So when designing a dryland program you should include a flexibility component. Recent findings in the realm of flexibility training are that dynamic stretches and movement patterns are an effective way to prepare for an exercise session. Dynamic movements and stretches can be designed to incorporate whole-body movements that can serve as an effective low-intensity warm-up while also addressing areas of inflexibility. Further attention can be given to tight muscle groups through static stretching at the conclusion of the dryland program.

Careful consideration needs to be given to selecting the proper exercises. Two concepts that can help guide exercise choice are transference and isolation. Transference is the ability of an exercise to strengthen muscles in a manner that will benefit a certain skill or task, in this case swimming. Transference can be further divided into direct and indirect forms. Direct transference involves choosing an exercise because the associated movements are directly related to a certain component of one of the major strokes. An example would be using the physioball prone streamline exercise (see page 136), because it directly mimics the streamlined position that swimmers hold off their starts and walls. Indirect transference involves choosing a certain exercise because the targeted muscle groups are similar to those used during a phase of one of the major strokes or choosing a certain exercise because it can transfer to a certain stroke component. An example would be selecting the lat pull-down exercise (see page 120) because it targets the latissimus dorsi muscle, which is a prime mover of the arms in each of the major strokes. Isolation involves choosing an exercise that emphasizes a certain muscle or muscle group with the goal of strengthening an area that (1) may be underdeveloped because of muscle imbalances, (2) is important for injury prevention, or (3) has been identified as an area of weakness by something in the swimmer's stroke profile.

Another choice concerns which model of dryland training to use—a traditional weight-training program or a circuit-based program. Traditional weight-training programs involve performing a certain number of sets and repetitions of one or two exercises at a time and then moving on to the next set of exercises. These programs are better reserved for swimmers near college age and older. In contrast, circuit-training programs involve a series of exercises performed one after another. After performing one set of an exercise, the person moves on to the next. Circuit programs are ideal when (1) the dryland program is being performed on a pool deck, (2) a large group of swimmers is participating in the program at the same time, or (3) a younger group of swimmers is training. An additional advantage of circuit programs is that they are time efficient, allowing a large number of exercises to be completed in a short time.

To maximize your gains when performing a traditional or circuit dryland program, give careful attention to the order in which you perform the exercises. All programs should begin with a 10-minute warm-up period consisting of dynamic flexibility exercises and low-intensity aerobics. Following the warm-up, you should incorporate several injury prevention and core stabilization exercises (choose from those in chapter 5). You should begin with total-body exercises that combine movements of the upper and lower extremities and progress to multijoint exercises and then isolation exercises. For example, when training the upper extremity and shoulder girdle, you could begin with a single-arm lawn mower (page 176), follow with a barbell flat bench press (page 70), and end with a dumbbell biceps curl (page 28). The underlying concept is to avoid performing the biceps curl first, which would fatigue the biceps brachii and decrease the overall weight that you could lift with the single-arm lawn mower exercise. A swimming analogy would be to avoid performing an exhaustive kick set before you perform your main quality freestyle set during a workout, because fatiguing your legs would limit your ability to get the full benefit from the freestyle set. Following completion of the main exercises, you can spend time on additional core stabilization exercises and static stretching and flexibility. Note that your final program should consist of more than three exercises; the limited number used in this case serve only as an example.

Another concept to consider is that of pushing and pulling exercises. Pushing exercises such as push-ups and bench presses primarily work the pectoral muscles and the triceps, whereas pulling exercises such as pull-ups and seated rows primarily work the lats and biceps. Because these types of exercises mirror each other in the muscle groups that they target, doing one after the other is often beneficial in a dryland program because the alternating nature of exercises allows one group to recover while the other is being exercised.

The next question to address is how many sets and repetitions of each exercise you should perform. The number of repetitions is dictated by the inverse relationship between volume and intensity. Exercise volume is equal to the total number of repetitions performed, and intensity is a measure of the effort being exerted when performing a given exercise. What this means is that as you increase the number of repetitions of a given exercise, the overall intensity at which you will be able to perform that exercise will decrease. For example, you may be able to perform 15 dumbbell kickbacks with 25 pounds (11 kg), but if you were to pick up a 40-pound (18 kg) dumbbell, you might be able to perform only 8 repetitions. This relationship becomes important, depending on your training goal. If you are trying to improve muscular endurance, you should choose a weight that allows you to perform 15 to 20 repetitions. If your goal is to build strength, you should use a weight that allows you to perform only 5 to 8 repetitions. Generally, when performing more repetitions (15 to 20) you should perform two sets, whereas when you are doing fewer repetitions (5 to 8) you should perform four or five sets. Your combination of sets and repetitions is probably appropriate for a given exercise if the targeted muscles feel fatigued during the last 2 to 3 repetitions of the final set. With circuit-training programs, the number of repetitions can be either predetermined or time dependent. For example, at one station you might perform 30 sit-ups (set number of reps) or as many sit-ups as you can in one minute (time dependent).

Your training goal in regard to endurance versus strength will depend on where you are in the season. The principle of periodization comes into play here. Periodization involves breaking the season into various phases, each with a different training goal. The underlying purpose is to prevent overtraining and maximize performance.

Dryland Training for Young Swimmers

An important consideration in training is the age of the swimmer. Not too long ago, strength, or resistance, training was considered inappropriate and potentially dangerous to the young athlete. Participation in resistance training was thought to increase the risk of injury to the growth plate, which could have negative consequences to the child's growth. But the safety and effectiveness of resistance training in youth is now well documented and supported by position or policy statements from the American College of Sports Medicine (ACSM), American Academy of Pediatrics (AAP), American Orthopaedic Society for Sports Medicine (AOSSM), and the National Strength and Conditioning Association (NSCA).

Resistance training helps young swimmers develop an enjoyable and positive outlook by increasing their chance of success through improved performance and decreasing their risk of injury. With a focus on fundamental fitness ability, resistance training also prepares them for the demands of in-water practices. Specific benefits may include improvements in muscular power, muscular endurance, total body strength, stability around joints, body composition, and bone mineral density, all of which can improve sport performance.

The research indicates that training-induced strength gains during preadolescence are possible if the training program is of sufficient duration, intensity, and volume. Current recommendations are that to produce strength gains, young athletes should perform two or three sets of 13 to 15 repetitions for each exercise. Training sessions should take place two to three days per week on nonconsecutive days. Note that these gains often result from adaptations in neuromuscular factors such as motor unit activation, recruitment, and coordination rather than increased muscle size (hypertrophy). Younger athletes do not have enough muscle-building hormones to cause muscle hypertrophy, but following puberty, training-induced gains in males and females are associated with increased muscle mass because of hormonal influences. Resistance training will not lead to increases in height, but no data indicate that training will stunt skeletal growth.

Before a young swimmer begins a resistance program, he or she should have sufficient emotional maturity to accept and follow directions. The athlete should also be able to understand the benefits and risks associated with a resistance-training program and specific exercises. When selecting exercises keep in mind that swimmers in a given age range can vary significantly in strength and coordination. Exercises should be selected on an individual basis and modified if necessary. Guidelines are provided throughout the text about exercises that may not be suitable for young swimmers, and examples are offered about how to modify exercises to make them more age appropriate.

When designing resistance-training programs for young athletes, a progressive and stepwise approach in exercise prescription is recommended. This approach stresses proper form and technique, adequate supervision of all training sessions, and a slow, stepwise progression of exercises. Kraemer and Fleck (2005) illustrate the importance of proper exercise selection and considerations for athletes of various ages (table 1.1).

When considering the important role of each muscle in the mechanics of the four swim strokes, you can see that keeping the muscles strong and well conditioned is critical to maintaining proper technique, improving performance, and minimizing risk of injury. Each of the following chapters includes exercises that target various muscles in a manner that contributes directly to swim-specific movements.

Table 1.1 Age-Related Resistance-Training Considerations

Ages	Considerations
7 and younger	Introduce child to basic exercises with little or no weight; develop the concept of a training session; teach technique; progress from bodyweight calisthenics, partner exercises, and light resistance; keep volume low.
8–10	Gradually increase the number of exercises; practice technique on all lifts; start gradual progressive loading; keep exercises simple; gradually increase volume; carefully monitor toleration to exercise stress.
11–13	Teach all basic exercise techniques; continue progressive loading of each exercise; emphasize technique; introduce more advanced exercises with little or no resistance; increase volume.
14–15	Progress to more advanced youth programs in resistance exercise; add sport-specific components; emphasize techniques; increase volume.
16 and older	Move child to entry-level adult programs after all background knowledge has been mastered and a basic level of training experience has been gained.

Adapted, by permission, from W.J. Kraemer and S.J. Fleck, 2005, *Strength training for young athletes,* 2nd ed. (Champaign, IL: Human Kinetics), 13.

CHAPTER 2 ARMS

The arms are extremely important in swimming because they are the link between the primary force-generating muscles of the upper extremity, the latissimus dorsi and pectoralis major, and the hands and forearms, which are the anchor points that propel the swimmer through the water. Chapter 1 compared the body to a chain that starts at the hands and extends all the way down to the feet. The main point was that, as a swimmer moves through the water, movements and forces are transmitted along the chain and that the chain is only as strong as its weakest link. Of course, the arm muscles also aid in generating the forces that propel you through the water. Those reasons should help you understand the importance of targeting the arm muscles with a dryland program.

The elbow divides the arm into an upper and lower component. The elbow is a hinge joint restricted to two movements, extension and flexion. Elbow extension occurs when you straighten your arm, moving the forearm away from the upper arm. Elbow flexion is the opposite, involving bending the forearm toward the upper arm. The structural framework of the upper arm is the humerus. The lower arm, typically called the forearm (figure 2.1, *a-b*), is supported by the radius and ulna. These three bones are the major attachment sites and

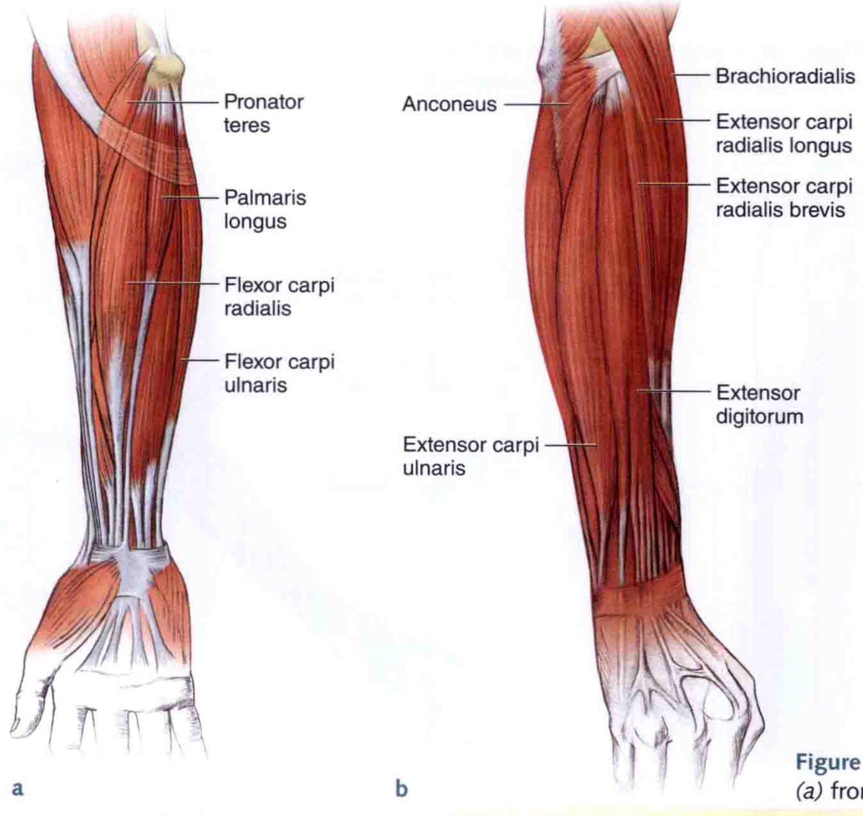


Figure 2.1 Forearm: *(a)* front and *(b)* back.

levers upon which the muscles of the arm and forearm originate and act on. The two primary muscle groups in the arms that are the target of the strengthening exercises in this chapter are the elbow extensors and elbow flexors. Both contribute to the maintenance of proper arm position and propulsion during each of the four competitive strokes.

The primary elbow extensor is the triceps brachii (figure 2.2). *Triceps* refers to its three heads of proximal attachment, and *brachii* refers to its origination in the arm. The medial and lateral heads arise from attachment sites on the humerus, and the long head crosses the shoulder joint and arises from the scapula (shoulder blade). The three heads unite to form the tendon that crosses behind the elbow joint and inserts onto the olecranon process of the ulna. The olecranon process forms the tip of the elbow when it is bent to 90 degrees. A much smaller triangular muscle called the anconeus assists the triceps in extending the elbow joint and is important as an elbow stabilizer. The anconeus is intimate with the lateral head of the triceps brachii; sometimes the fibers of the two muscles blend into one another.

The primary elbow flexors are the biceps brachii and the brachialis (figure 2.3). As the name implies, the biceps has two heads, a long and a short, both of which cross the shoulder joint and attach to the scapula. The two heads fuse to form a common tendon that crosses the front of the elbow joint to attach to the radius approximately 1.5 inches (4 cm) past the elbow. Besides being an elbow flexor, the biceps brachii contributes to the forearm movement of supination, which is the position when the palm is facing up. Your hands would be in this position to carry a bowl of soup. The brachialis lies beneath the biceps brachii and arises at the midpoint of the humerus. It attaches to the ulna just after it passes anteriorly to (in front of) the elbow joint. A smaller muscle that at times contributes to elbow flexion is the brachioradialis. This muscle arises from the lateral aspect of the humerus just above the elbow and travels along the outer part of the forearm to attach to the radius just above the wrist joint.

Despite difference in stroke mechanics, freestyle, butterfly, and backstroke have similar activation patterns of the elbow flexors and extensors during the pull phase. As the swim-

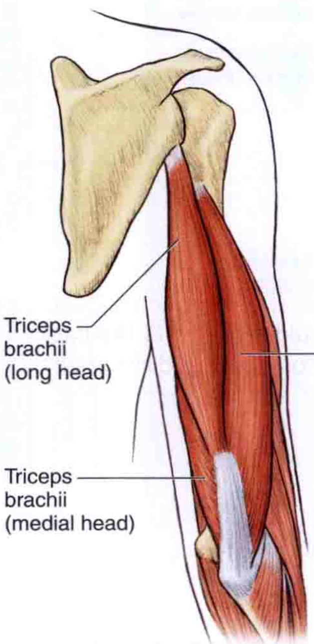


Figure 2.2 Triceps brachii.

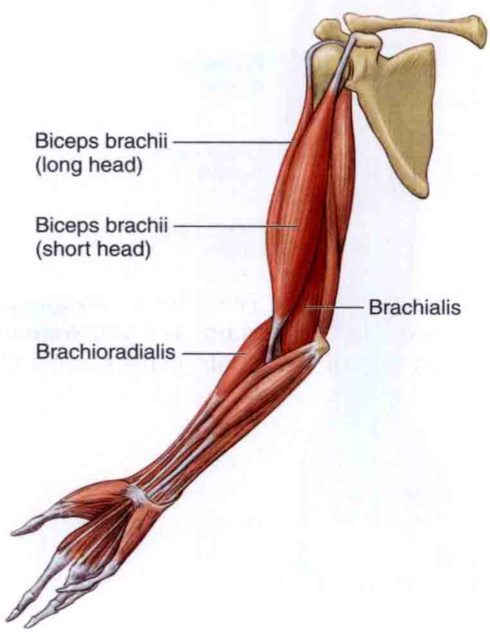


Figure 2.3 Biceps brachii, brachialis, and brachioradialis.