However, as systems of health care and payment continue to change, all rehabilitation venues, and therefore all rehabilitation clinicians, will eventually have to deal with outcomes assessments more formally than they typically do now. Better clinicians are proactive rather than reactive, and this is especially true in the realm of outcomes.

Basic Components of Therapeutic Exercise

In the total rehabilitation program, there are two basic elements, therapeutic modalities and therapeutic exercise. Modalities are used to treat and resolve those effects first seen in injury: spasm, pain, and edema. Although modalities are an essential component of a rehabilitation program, they will not be presented in detail in this text. Therapeutic exercise (therex) is an essential and critical factor in returning the patient to sport participation or normal activity. If the therapeutic exercise program is to be effective, however, specific parameters must be addressed sequentially. Each of these parameters must be restored to at least preinjury levels if the patient is to safely resume full sports participation or normal activity. These parameters in their proper sequence are

1. flexibility and range of motion,
2. strength and muscle endurance,
3. balance, coordination, and agility,
4. functional activity, and
5. performance-specific activity.

Each of these parameters is based on the previous parameter's successful completion, much like a pyramid (figure 1.2), stones placed one on the other, layer by layer until the structure is complete. This concept will become clearer as we discuss each parameter.

At the base of the pyramid is relief of pain and other secondary effects of injury such as joint effusion or edema and muscle spasm. These factors are managed with modalities for the most part. Specific applications of manual therapy and correction of deviations are presented throughout the text. The remaining pyramid levels are addressed using various therapeutic exercise techniques. Flexibility and range of motion must be achieved after pain relief. Once mobility is achieved, gains in strength and muscle endurance are made. As the patient progresses up the pyramid, each step is achieved until the top of the pyramid is reached, where

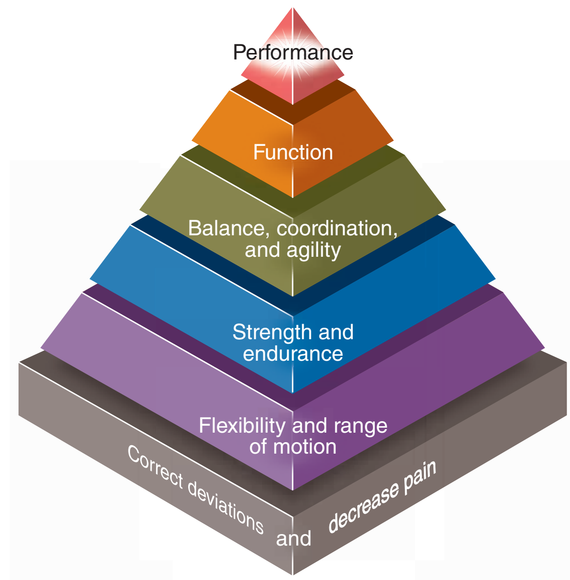

Figure 1.2 Pyramid demonstrating the elements and progression of a rehabilitation program, one parameter advancing from the foundation set by the previous parameter.

performance-specific exercises that mimic the patient's normal activities are included in the rehabilitation program. Achieving this last level occurs prior to the patient's return to optimal function.

It should be noted that the pyramid's first level includes correction of deviations; this part of the first level is an important aspect of rehabilitation programs that deal with nonacute injuries. This element applies to injuries that occur over time (such as tendinopathies) and are not the result of a sudden trauma. This added first-level pyramid step includes identifying the precipitating factors—etiological factors—that cause the injury to occur. This is a crucial step in rehabilitating chronic or repetitive injuries because if steps are not made to identify the reason the patient developed the condition, the problem will return once the patient resumes normal activities. In these cases, clinicians take on the role of detective to identify the source of pathology and make efforts to correct deviations and causative factors.

Flexibility and Range of Motion

A properly designed therapeutic exercise portion of a rehabilitation program places a priority on regaining lost range of motion and flexibility first. Achieving flexibility early in the therapeutic exercise program is necessary for two important reasons. First, the activities that follow require good mobility of the affected area. To make this point clear, consider how handicapped a hurdler would be if the hamstrings were too tight. Strength and coordination would be of little importance if the flexibility needed to extend the limb over the hurdle was lacking.

The second reason to emphasize regaining range of motion first in the therapeutic exercise program is the impact of the healing process (discussed in chapter 2). As injured tissue heals, scar tissue forms. As scar tissue matures, it contracts and becomes more permanent. These effects are important in eventually minimizing the scar, but they can also be detrimental because as the tissue forms, contracts, and matures, it attaches to and pulls on adjacent tissue and becomes stronger with improved adhesive bonds and its maturation, causing loss of motion of soft tissue structures in the area and of joints when scar tissue crosses a joint.

During healing there is a window of opportunity during which scar tissue mobility can be influenced and changed. Once that time frame has passed, the likelihood of successfully achieving full range of motion is diminished considerably. Although restoration of other parameters is also sought during the first stage of therapy, flexibility must be the primary emphasis.

Strength and Muscular Endurance

As an injured site's healing and mobility progress, achieving normal strength and muscular endurance becomes the priority. With any injury some strength is lost. The amount of strength and muscle endurance lost depends on the area injured, the extent of the injury, and the amount of time the patient has been disabled by the injury.

Of all the parameters of therapeutic exercise, strength is probably the most obvious and most frequently sought to restore after an injury. It is obvious because it is easily understood that a weightlifter with a sprained knee cannot return to competition until full knee strength is achieved. It is just as obvious that an auto mechanic must have normal shoulder strength to return to work after suffering a dislocation.

The need for muscle endurance and the relationship between muscle strength and endurance are sometimes not considered, however. If a baseball pitcher has good rotator cuff strength but no endurance beyond 10 repetitions, how will he be able to pitch more than a couple of innings in a game? If a UPS driver can leg press 225 kg (496 lb) but can climb only one flight of stairs, will she be able to deliver heavy packages for an entire shift?

Muscular strength and endurance are two dimensions within a continuum of muscle resistance. Essential concepts of muscle strength and endurance are presented in chapter 7.

Balance, Coordination, and Agility

Balance, coordination, and agility are often omitted in a therex program. It is too often assumed that because range of motion and strength are restored, the patient is ready to resume full sport participation or normal activity. This is not the case at all. Impaired balance and coordination—either from injury to the structures controlling these parameters or from lack of practice in a specific skill—increases risk of injury.[41]

A variety of factors affect a patient's balance, coordination, and agility. A number of factors in turn are affected by these elements, including muscular power, skill execution, and performance. (The factors that affect and are affected by balance, coordination, and agility are discussed in chapter 6.) Adequate flexibility and strength must be achieved before appropriate balance and coordination skills can be developed. Coordination and agility are based on the patient's having enough flexibility to perform the skill through an appropriate range of motion and enough strength, endurance, and power to perform it repeatedly, rapidly, and correctly. This is why balance, coordination, and agility are presented later in rehabilitation: they are based on the foundation of good flexibility, strength, and even muscle endurance.

Although not all health care professionals emphasize this parameter, a total rehabilitation program must include the recovery of balance, coordination, and agility. Consider a tennis player who has suffered a back injury that has kept him out of competition for 2 months. The timing of his serve, the coordination of his response to his opponent's serve, and the agility of his feet in sudden lateral movements on the court may all be impaired. In a normal rehabilitation program, simple balance exercises are introduced early in the therapeutic exercise program, but coordination and agility are not emphasized until after strength and range of motion are achieved.

Functional and Performance-Specific Activity

Specific skill performance is the last step before a patient's return to optimal function and participation. Accurate execution of functional and performance-specific skills requires attainment of all previous parameters first. Sometimes it is difficult to determine when agility exercises end and functional exercises begin. This difficulty occurs because some agility exercises could be considered functional exercises. Likewise, some functional exercises could be thought of as performance-specific exercises for some sports or job tasks. For example, an agility exercise may be jumping side to side over hurdles or cones, but that could also be a functional exercise for someone who is a soccer goalie or a football defender. Jumping side to side may also be a performance-specific exercise for a tennis player. How these exercises are labeled is based primarily on when in the program they occur and what the goal is for the specific exercise. If the goal is to increase speed of motion, then it is likely an agility exercise, but if the goal is to improve lateral motion accuracy, it is likely a functional exercise. It becomes a performance-specific exercise if the patient is on the field or court and performing a specific sport skill that involves side-to-side movement.

There is an evolution of exercises in the last half of the rehabilitation program that moves from an emphasis on balance and coordination to an ability to execute normal drills that mimic the patient's actual activities. The last step before returning to normal activities involves the execution of these performance-specific activities. In this final stage patients regain the confidence they need to perform at their prior activity level. Concepts and examples from this phase of rehabilitation are discussed in chapter 9. When the patient can achieve specific goals established for these activities, the rehabilitation clinician can be assured that the final long-term goal of fully rehabilitating the patient has been achieved.

CLINICAL TIPS

Therapeutic exercise must address the following physiological parameters in proper order: first, flexibility and range of motion; second, muscle strength and endurance; third, balance, coordination, and agility; fourth, functional performance; and fifth, performance-specific activities.

Prehabilitation

Prehabilitation is the use of therapeutic exercises in advance of a surgical procedure to improve the functional capacity of the patient so that the patient may withstand the effects of inactivity after an orthopedic surgery.[42] It has been demonstrated that patients who perform preoperative exercises do better postoperatively in both short-term[43] and long-term[44] results. Not all patients have the opportunity to perform preoperative therapeutic exercises prior to surgery, but whenever possible, it is advisable.[45]

It is well known and accepted that, in addition to the inflammatory healing effects (pain, swelling, and muscle spasm) that follow surgery, motion and strength deficits also result. Whatever strength level the patient has at the time of surgery is reduced after surgery; it makes intuitive sense, then, that the more strength a patient has prior to surgery, the more strength she will have immediately after surgery. For example, if patient A has quadriceps strength that allows him to lift 30 lb with his knee extensors, and patient B, who has an equivalent injury to patient A, has quadriceps strength that allows him to lift 50 lb with his knee extensors preoperatively, after each of them undergoes the same surgery, they will each lose 20 lb of strength. Postoperatively, patient A can now lift 10 lb and patient B can now lift 30 lb (figure 1.3).

Studies have demonstrated that patients undergoing prehabilitation not only recover from surgery better but their strength gains are more rapid after surgery, and they have less postoperative pain.[46] Preoperative rehabilitation exercises include many of the same exercises used in postoperative rehabilitation. The use of neuromuscular electrical stimulation has shown beneficial effects in preoperative strength gains.[47] Efforts to optimize range of motion and soft tissue mobility along with gains in strength and function are also part of the prehabilitation program. Treatments should stay

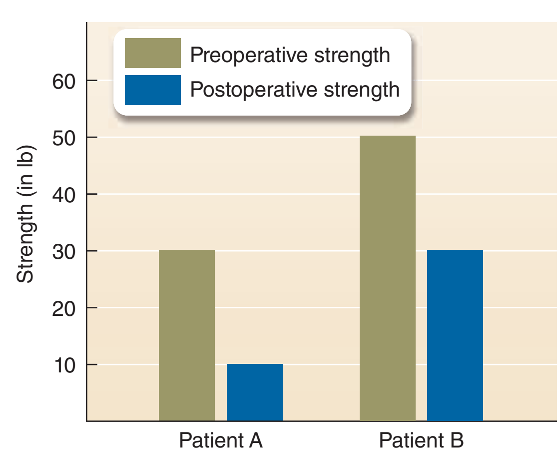

Figure 1.3 Example of differences in preoperative and postoperative strength measures between two similar patients. The stronger a patient is before surgery, the stronger a patient is after surgery.

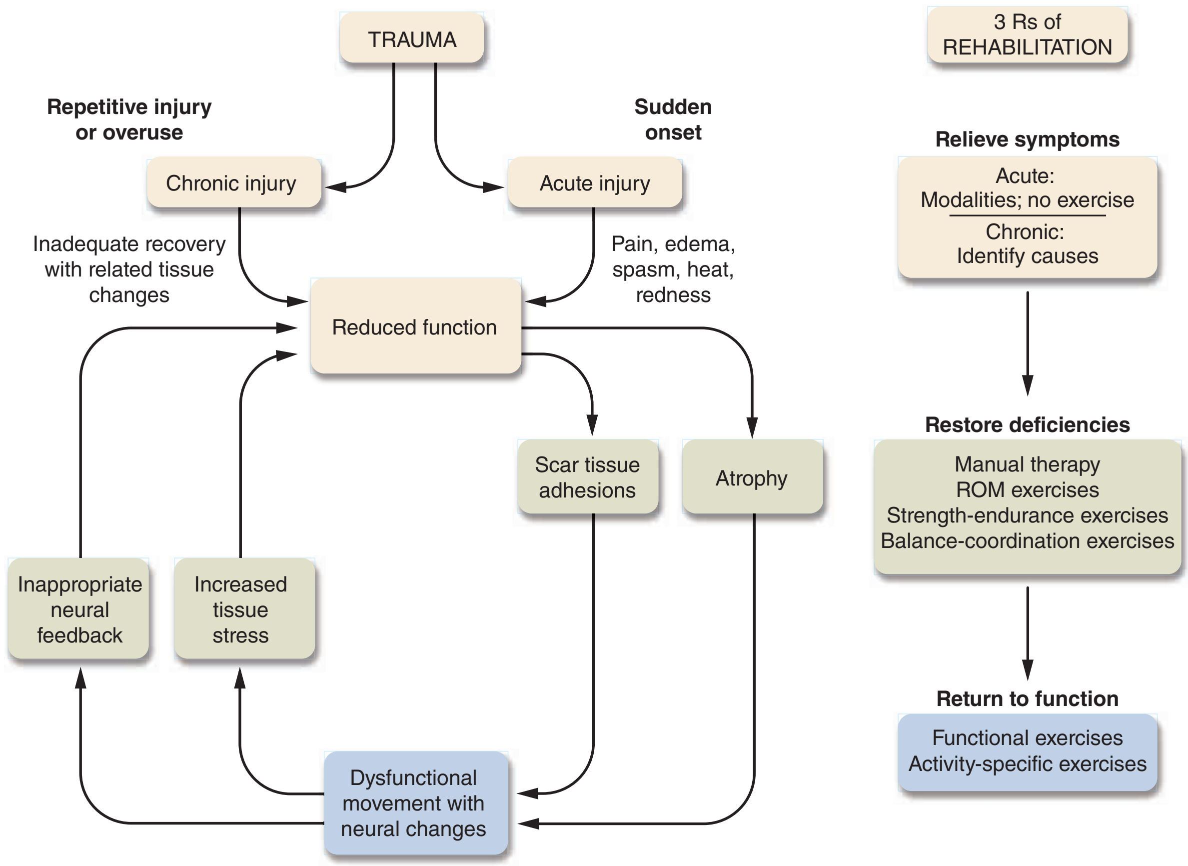

Figure 2.8 The injury process and appropriate types of rehabilitation techniques.

similar, electrical stimulation may also have the same effects when applied to ligaments.

Electrical stimulation applied to muscles may relax muscle spasm.[13] When facilitating muscle contraction, electrical stimulation may also assist in relieving local edema by pumping fluid into the lymph system, which reduces pain. With less pain, the patient may exercise more willingly.

CLINICAL TIPS

Factors that affect healing include therapeutic modalities, drugs, surgical repair, patient's age, systemic diseases suffered by the patient, injury size, infection, nutrition, spasm, and swelling. The clinician can influence some of these factors such as modality selection to reduce spasm, pain, and swelling; infection prevention; encouraging the patient to eat nutritionally; and urging the patient to maintain optimal health in the presence of systemic diseases. Since drugs have the ability to affect healing, the clinician should be aware of all medications the patient is taking and the effect they may have on the healing process.

Electrical stimulation is used to retard muscle atrophy after injury or prolonged inactivity. Electrical stimulation is used to facilitate muscle contraction and encourage reactivation and recruitment of dormant fibers.[13] During short-term denervation, it may facilitate muscle contraction until nerve function is restored. Electrical stimulation may also be used to reduce or relieve muscle spasm.[13]

After the inflammatory phase, heat can be advantageous when applied prior to exercise. It may increase circulation to encourage healing and better exchange of nutrients and waste products, relax muscles to allow better exercise execution with less pain, and reduce tissue viscosity to make an area more pliable for stretching.[13] It is believed that ultrasound and diathermy may speed healing and enhance the effects of exercise by improving motion with less pain.[13]

Ultrasound has the benefit of producing thermal as well as mechanical effects. A contraindication to continuous ultrasound is in the acute inflammatory phase, when heat is deleterious; at that time, pulsed ultrasound is indicated. As a source of deep heat, ultrasound may be a useful prestretch application for small-area tendon and capsular adhesions that lie deeper than superficial heat can reach effectively.

It is important for the rehabilitation clinician to know the desired results and select a modality that best facilitates those results. As the patient's rehabilitation program progresses, fewer modalities are required because the injury is more closely approaching normal function and new tissue injury is absent. For example, as the patient enters the final stages of therapeutic exercise, ice is not needed after the therapeutic exercise program. If the patient continues to have new swelling or increased pain that requires the application of ice after an exercise routine, an examination is required because these symptoms should not occur late in rehabilitation. Table 2.9 provides a suggestion for possible modalities and manual therapy techniques to use throughout the rehabilitation process. This table should be used only as an example of suggestions for these applications; specific selections are individually determined and based on the patient's problems and needs.

Drugs

Patients often consult with a rehabilitation clinician for information about the drugs that have been prescribed after injury. Therefore, the clinician should have a basic understanding of medications, be aware of his or her own limited knowledge, and readily refer the patient to either the physician or a pharmacist for information beyond the scope of his or her knowledge.

Clinicians should remember certain general rules of thumb about medication. All drugs, even vitamins, have the potential to produce undesirable side effects. Any drug should be used with caution and taken according to recommendations of the physician, pharmacist, or manufacturer of over-the-counter (OTC) medications. If undesirable side effects occur, the physician should be contacted for instructions to either discontinue the medication or alter its administration. All drugs have a **duration of action**, the length of time that the amount of drug in the blood is above the level needed to obtain a minimal therapeutic effect. This length of time is determined by the half-life of the drug. A drug's **half-life** is the amount of time it takes for the level of the drug in the bloodstream to diminish by half. The frequency with which the drug is administered is based on its half-life. The shorter the half-life, the more often the drug must be administered to obtain a minimal therapeutic effect. The example given in Houglum et al.[111] demonstrates this concept: Naproxen, with a half-life of about 14 h, is administered twice a day, whereas ibuprofen, with a half-life of around 2 h, is administered three to four times a day.

A goal of drug administration is to achieve a steady state. A **steady state** occurs when the average level of drug remains constant in the blood, that is, when the amount absorbed into the blood equals the amount removed through metabolism or excretion. After the first few administrations of the drug, the amount of drug in the bloodstream increases until this steady state is achieved. As a rule of thumb, a steady state is achieved after the dosing of the drug has continued for a time equal to 4 to 5 half-lives.[111] For example, using 5 half-lives to calculate the time needed to reach steady state, if a drug has a half-life of 12 h and is given twice a day, a steady state is achieved by the middle of the third day (5×12 h). If a drug has a half-life of 2 h and is administered every 6 h, a steady state occurs after the third dose (5×2 h) because the first dose is at time 0, the second is at 6 h, the third at 12 h, and so on. The difference between 4 and 5 half-lives is nominal: After 4 half-lives, a steady state of 94% is reached, and it increases to 97% after 5 half-lives.[111] A patient's compliance in taking medication is important for achieving a steady state and the desired results. If a patient fails to take prescribed medication, the intended results may not be achieved. By the same token, taking more than the prescribed dosage may not produce better results faster. In fact, it can be deleterious. "More is better" does not apply to drug dosages. Taking higher or more frequent doses of a drug causes higher concentrations and may cause toxic side effects. Taking two different anti-inflammatory drugs, whether they are prescription or OTC medications, should also be avoided because it is equivalent to increasing dosage and can be dangerous. These precautions should be pointed out to the patient when medications are given.

Most drugs taken by mouth are absorbed in the small intestine. If medication is taken with liquid, a full glass of liquid is advisable, not just a swallow. The liquid helps dissolve the medication and also increases the speed with which the drug moves from the stomach to the small intestine. If a drug is to be taken with food, it is absorbed at a slower rate, and the food may reduce otherwise irritating effects on the stomach.

Other factors that alter drug absorption include exercise immediately after ingestion, since blood normally allotted to the gastrointestinal tract is shunted to working muscles. With delayed movement of medication from the stomach to the small intestine, stomach lining irritation may increase.[111] For this reason, it may not be a good idea to take an anti-inflammatory medication immediately before exercise, especially when the stomach is empty.

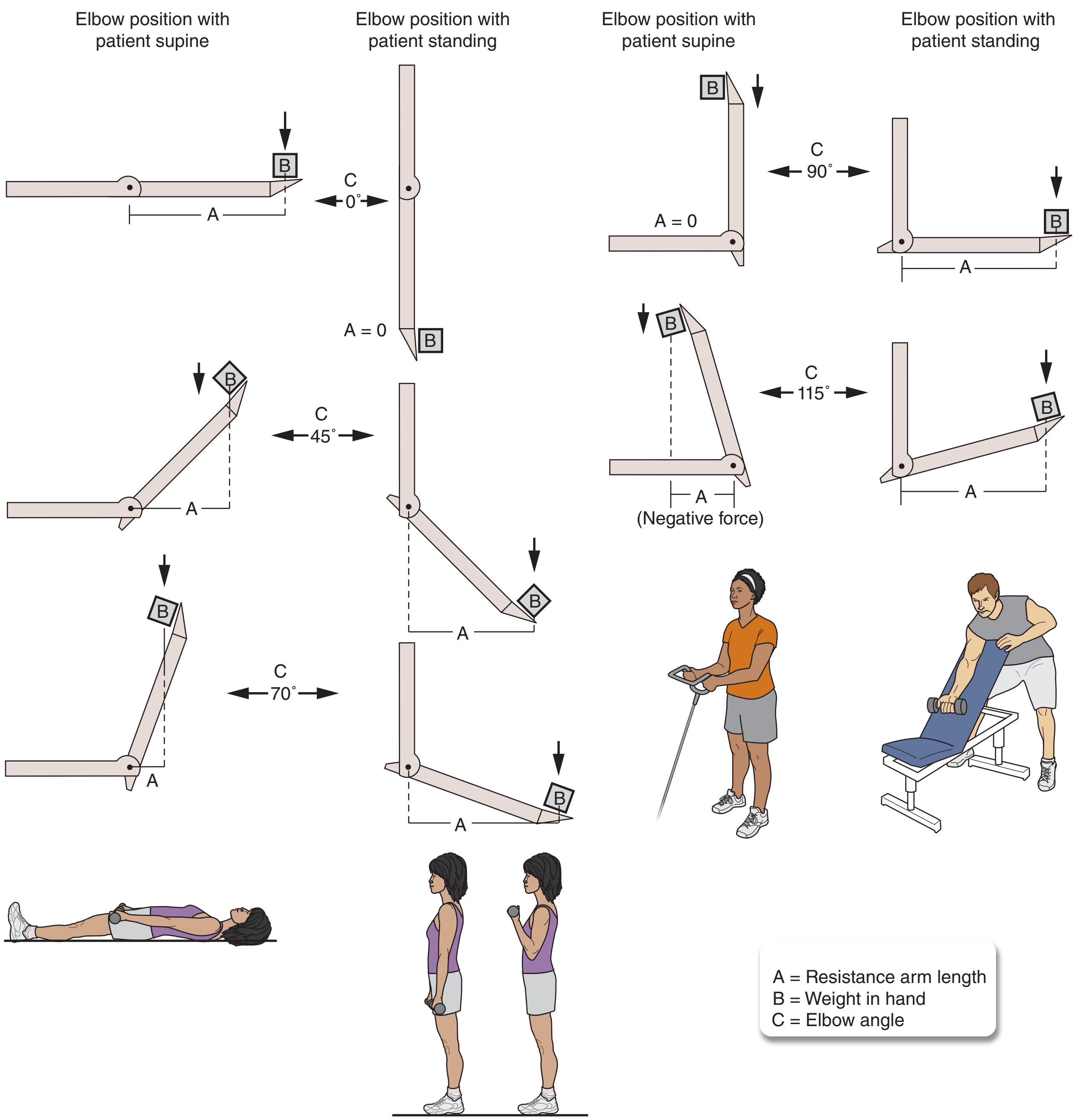

Figure 3.15 Changes in position cause changes in resistance arm when using free weights. Resistance is greatest at 0° when supine and 90° when standing.

a muscle can be lengthened in a relaxed condition without producing tension or any additional stretch. For example, the greatest physiological advantage of the brachialis is with the elbow in full extension, and the greatest physiological advantage for the soleus is with the ankle in dorsiflexion.

As a muscle shortens, its physiological advantage becomes progressively less until it is unable to produce a force, as illustrated in figure 3.16. Although specific muscles shorten to varying percentages of their resting length, on average, a muscle can shorten from 50%[6] to about 70%[7,8] of its resting length. At that point, all the cross-bridges are used between actin and myosin fibers, allowing no additional fiber shortening.[9] Muscle physiology is presented in greater detail in chapter 7.

Multi-Joint Muscles

If a multi-joint muscle shortens as far as possible, it affects the position of all the joints it crosses. For exam-

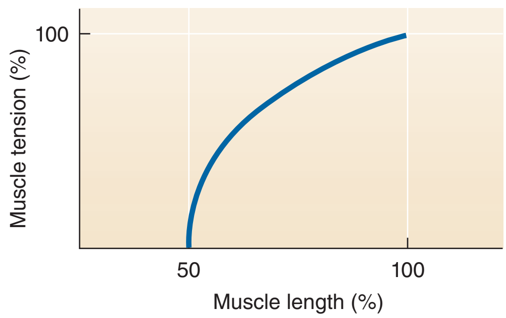

Figure 3.16 Physiological length–strength relationship of muscles. A muscle has the greatest physiological strength at its full resting length and becomes weaker as it shortens until it cannot shorten any farther.

ple, when the hamstring group shortens unimpeded, it produces hip extension and knee flexion. However, since the muscle exhausts its ability to shorten before both joints reach their end motions, the hamstrings cannot fully complete motions at both joints simultaneously. This condition is called **active insufficiency**. Likewise, if a multi-joint muscle is stretched to its maximum length over the joints it crosses, it does not have enough length to allow all of the joints it crosses to reach their end positions; this condition is called **passive insufficiency**. Active and passive insufficiency are concepts unique to multi-joint muscles.

Because of active insufficiency, when a two-joint or multi-joint muscle contracts, it should be elongated at the stabilized, nonmoving joints so it can work optimally at the moving joint. For example, if you want to maximize efforts of the hamstrings during a knee flexion exercise, the best position for the patient is sitting so the hamstrings are lengthened at the hip, providing the muscle with the length it needs to create more force at the knee. If the patient is prone, the hamstrings are already shortened at the hip and will be unable to fully contract at the knee; full knee flexion cannot occur actively.

Remember that as any muscle shortens, its ability to produce force declines, so you want a muscle to begin movement at its optimal length when maximum force is required of the muscle. When you want to produce as much force from a two-joint or multi-joint muscle as possible, the muscle should be placed on stretch at the nonmoving joints as it provides motion at the joint for which the muscle's force is needed. Likewise, when exercising a single-joint muscle for optimal output, the muscle begins the exercise at its lengthened position. These positions permit all the muscle's available physiological length (and hence its strength) to be used at the desired site and produce optimal results.

We must consider passive insufficiency of multi-joint muscles in two instances: when we want to stretch a muscle, and when we have pathologically restricted muscle mobility. Passive insufficiency occurs because the opposing muscle's flexibility prevents the desired movement from occurring. For example, if a person has limited mobility of the gastrocnemius muscle, he can dorsiflex the ankle normally when his knee is flexed, but when he dorsiflexes his ankle with an extended knee, the restricted gastrocnemius is on stretch and prevents full dorsiflexion from occurring. If we want to stretch a muscle that moves two or more joints, we have to be sure we position each joint it crosses in a manner that will create optimal results from the stretch; each joint must be positioned in the direction opposite to the muscle's pull. We can use the hamstrings as an example. Since we must move a muscle in the direction opposite to its pull to stretch it, and the hamstring group pulls the hip into extension and the knee into flexion, then stretching the hamstrings requires opposite movement at both joints that it moves: We must move the hip into flexion and the knee into extension to create an effective stretch on the hamstrings.

VIDEO Go to the online video and watch **video 3.2**, which demonstrates multi-joint positioning for strength.

VIDEO Go to the online video and watch **video 3.3**, which demonstrates multi-joint positioning for flexibility.

Summation of Forces

Summation of forces is especially important during the latter phases of a therapeutic exercise program. The **summation of forces** is a sequence of movements timed so that each movement contributes to the next movement to produce a desired outcome. For the summation of forces to be successful, the forces from each part must be correctly timed, and each successive joint from which the activity occurs must be stabilized. This is more easily understood with an example: A baseball pitcher goes through a series of sequential movements starting with the hips, progressing to the trunk, then the shoulder, the elbow, and finally the wrist and hand to pitch a ball. Acceleration of the ball occurs by a that mimic sport or work activities occurs as soon as the patient's abilities allow.

The patient must perform the activity accurately. To encourage this, the difficult proprioceptive activities occur early in the therapeutic exercise session rather than later when the patient is more fatigued and coordination is more difficult.

Lower-Quarter Progression

Although specific exercises are addressed in part IV as specific therapeutic exercise programs for the various areas of the body, a brief description of proprioceptive programs is presented here.

Static balance activities begin with the single-leg stance with eyes open, using all three balance feedback systems. The patient stands on the foot of the involved leg with arms at sides. The goal is to stork stand for 30 s holding the arms at the sides without touching the elevated foot to the floor. Patients who have difficulty with the stork stand can begin with a stance in a tandem position, with the toe of one foot touching the heel of the foot in front of it (figure 6.7*a*); this is more difficult with the injured leg in the back position. Without using the arms to balance, the patient stands in this position for 30 s with eyes open. After accomplishing either the single-leg stance (figure 6.7*b*) or tandem position with eyes open for 30 s, the patient performs it with the eyes closed for 30 s to eliminate the visual input and then with eyes open while rotating the head left to right while maintaining balance for 30 s to eliminate the vestibular input. Balance activities progress from a single-leg stance on the floor to a single-leg stance on an unstable surface such as a mini-trampoline, foam rubber pad, or 1/2 foam roller, eyes open, eyes closed, eyes open with left-to-right head rotation (figure 6.7*c*), and eyes closed with left-to-right head rotation.

You can also create increased difficulty in a single-leg stance by having the patient perform a distracting activity such as playing catch. This can become even more challenging if the ball is weighted. If the patient normally participates in a ball-related sport, it is useful to use that ball to play catch to provide the patient with an emotional connection to his or her sport during the rehabilitation process.

a b c

Figure 6.7 Static balance progression: *(a)* tandem stance balance, *(b)* stork stand balance, *(c)* stork stand on 1/2 foam roller.

The patient can also perform static-balance activities in a sport-specific position. For example, a gymnast can perform the single-leg stance on a balance beam or with the hip in lateral rotation. A tennis player can perform static balance activities on the balls of the feet with hip and knee flexion. A wrestler can perform static balance activities on the unstable surface of a wrestling mat.

After having mastered static balance, the patient progresses to dynamic balance. These activities include sport demands such as running, lateral movements, and backward movements. Lateral movements might include lateral shuffles or leaps to a target for accuracy, later advancing to dynamic activities for speed such as jumping, cutting, twisting, and pivoting. They begin as low-level activities, performed at a slow speed with balance and control, and progress to faster speeds. Some activities, such as jumping, can begin with the use of both legs but then progress to unilateral activities as the patient gains skill, confidence, and accuracy in execution. Reminding the patient to maintain core control during these activities may be required, especially in the early days of their execution. Plyometrics can be incorporated into the later stages of proprioceptive exercises within the therapeutic exercise program. Plyometrics is a specialized system of exercises used only in the final stages of a program when the patient has good strength, flexibility, and control. Plyometrics are discussed in chapter 8.

In the final stages of these dynamic movements, exercises advance to mimic specific performance requirements. These exercises represent the true agility activities required of the patient in his or her normal activities. You must know the required activities and understand the stresses applied in the patient's sport or job to be able to design this part of the therapeutic exercise program. If the patient is returning to a job, then the tasks required during normal working activities are used as the performance-specific exercises in the final rehabilitation phase. These exercises fine-tune the patient's agility and restore his or her confidence in a successful return to work without fear of reinjury or performance deficits. Many of these exercises are discussed in chapter 9.

The use of braces, sleeves, and tape to enhance proprioception with ankle and knee injuries is still a matter of some dispute. As was previously mentioned, there is evidence that proprioception input from skin and subcutaneous sensory receptors helps in the perception of motion.[3,12,64] There is also evidence that elements of proprioceptive function may be improved with bracing.[65-67] One investigator found that the benefit of joint support (orthotics or bracing) is inversely proportional to the proprioceptive ability of the joint, [68] so injured people who demonstrate balance deficiencies may benefit from using a brace or orthotic until proprioception is restored. It seems that the investigators who found no benefit to using braces performed their investigations on normal people[69] or on those whose injuries and rehabilitation occurred more than 2 years earlier. It has been demonstrated that people with proprioceptively deficient knees rely on their cutaneous proprioceptors more than uninjured people;[70] it may be that tape or other types of support work by facilitating these cutaneous receptors to act as position-sense monitors. Most studies on proprioception and kinesthesia have been able to demonstrate an improved awareness about joint position or joint sense, but no evidence thus far demonstrates that joint stability is enhanced during functional activities with the use of such devices.[71] Complicating the decision to use braces or sleeves even more, one study offered evidence that healthy people did improve their proprioceptive performance with the use of prophylactic bracing.[65]

Although it has been revealed that cutaneous receptors are the "second-string" receptors the body uses for proprioceptive information,[3] there is conflicting evidence to support or discourage the use of braces and sleeves;[72] therefore, you must decide whether to use them on an individual basis. If the patient feels more confident and better able to perform when wearing a brace or splint, the device may provide enough psychological benefit to warrant its use.

Upper-Quarter Progression

Although most lower-extremity sport activities are arguably closed-chain activities, upper-extremity activities are both open and closed chain. The patient's performance requirements in relation to open- or closed-chain activities will determine the extent of the proprioceptive exercises to be used within the therapeutic exercise program. A well-rounded program should include both open and closed kinetic chain activities, but end-program emphasis is determined by the demands of the patient's normal activities. For example, a baseball pitcher's demands are open kinetic chain, so the majority of proprioceptive exercises for a pitcher should be of this type. A gymnast performs both open and closed kinetic chain activities and thus should do a combination of open and closed kinetic chain proprioceptive exercises, but a cyclist performs closed kinetic chain activities, so the program for this patient should include primarily closed kinetic chain exercises.

Initial open kinetic chain proprioceptive exercises can include proprioceptive neuromuscular facilitation rhythmic stabilization techniques. Rhythmic stabilization can progress to closed kinetic chain exercises. In a closed kinetic chain, the exercise can progress from co-contraction without movement, to movement on a stable surface, to movement on an unstable surface. For example, the patient can either be positioned on a Swiss ball and move his or her body with the hands anchored on the floor, or be positioned with hands moving the ball and the body supported on a table (figure 6.8). This activity can start with bilateral support and then advance to using only the involved arm. As with lower-quarter exercises, upper-quarter cues should include patient reminders to maintain core stability and proper neck and back alignment throughout the exercise progression.

1. Patient lies prone on a Swiss ball with feet off the floor. Patient begins with both hands on the floor and then raises the uninvolved arm to balance for 30 s (figure 6.8*a*).

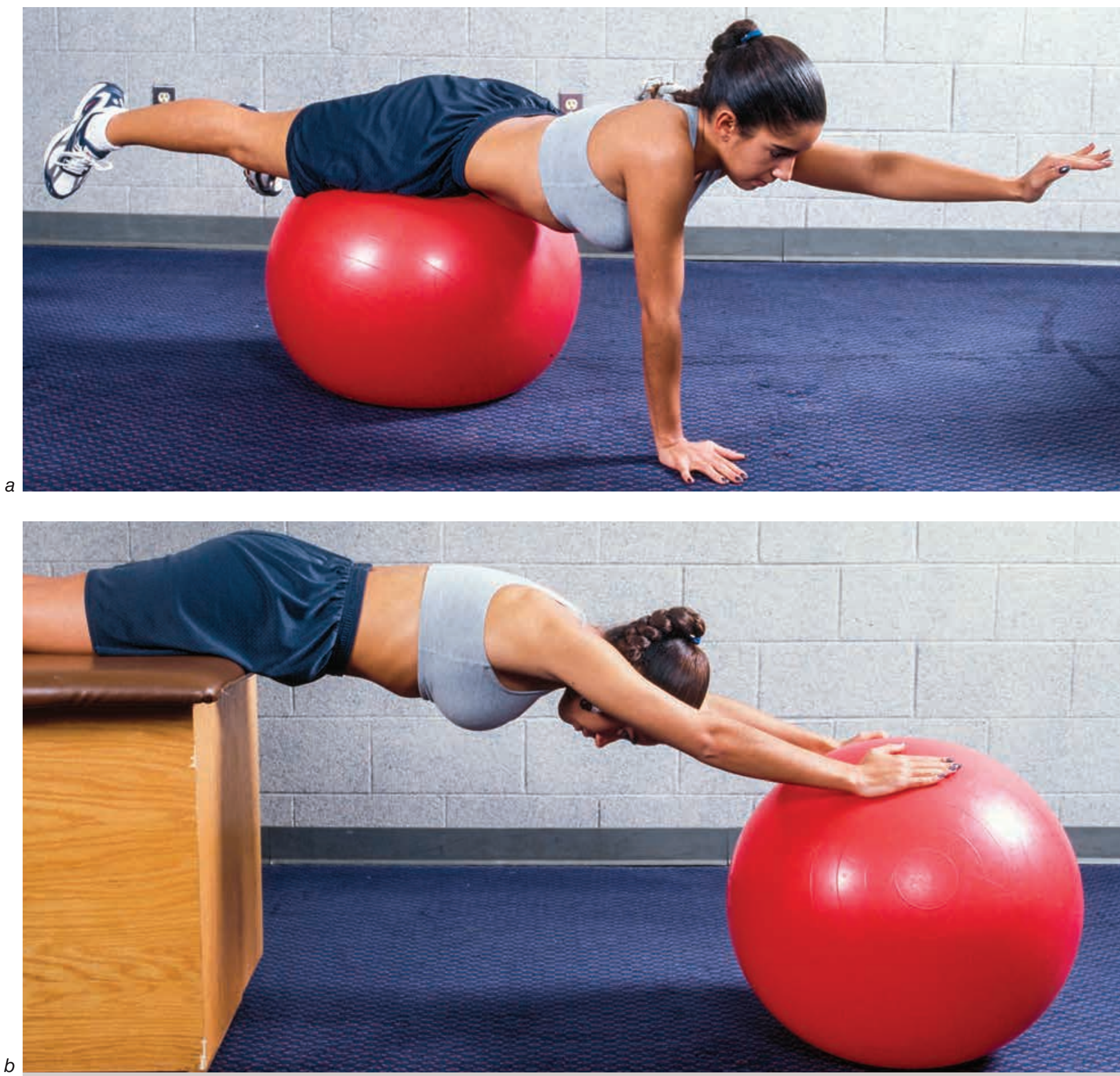

Figure 6.8 Proprioception exercises for the upper quarter on the Swiss ball: *(a)* Patient is supported by a Swiss ball only, *(b)* patient is supported by a table while moving a Swiss ball.