FUNDAMENTAL CONCEPTS

1

OUTLINE

INTRODUCTION

The underlying philosophy of this book is that there is a continuing need to "get back to basics." This philosophy is especially pertinent in this era of time-limited treatments, advancing technology, and the need to justify the initiation or continuation of care by practitioners.

Muscle function, body mechanics, and simple treatment procedures do not change. With respect to musculoskeletal problems, the underlying purposes of treatment have been, and continue to be, to restore and maintain appropriate flexibility, extensibility, range of motion, good postural alignment, and muscle balance.

It is essential for practitioners to choose and effectively perform tests that aid in solving problems, whether to provide a differential diagnosis, establish or change treatment procedures, improve function, or relieve pain. Of paramount importance for students and clinicians is the ability to think critically, to apply objectivity, and to use the caution and care needed for appropriate objective tests and measurements so that clinical reasoning can be both accurate and meaningful.

The role of prevention of musculoskeletal problems, as predicted in previous editions of this text, has become an increasingly important issue. Health practitioners play an effective role in promoting wellness if they are aware of adverse effects of muscle imbalance, faulty alignment, and improper exercise.

A thorough understanding of musculoskeletal assessment and those painful muscle conditions associated with poor posture enables practitioners to develop safe and effective home programs for their patients. The costs to society for treatment of common problems, such as low back pain (LBP), have reached a critical point. Many cases of LBP are related to postures that can be addressed, corrected, and alleviated.

Manual Muscle Testing

Muscle testing is an integral part of physical examination. It provides information, not obtained by other procedures, that is useful in differential diagnosis, prognosis, and treatment of neuromuscular and musculoskeletal disorders.

Muscle *length testing* is used to determine whether the muscle length is limited or excessive. A muscle that is too short will limit normal range of motion and a muscle that is elongated may allow too much range of motion that leads to instability of adjacent joints and tissues. When stretching is indicated, tight muscles should be stretched in a manner that is not injurious to the structures or to the body as a whole. Range of motion should be increased to permit normal joint function unless restriction of motion is a desired outcome for the sake of stability (1, 2).

Muscle *strength testing* is used to determine the capability of muscles or muscle groups to function in movement as this has an impact on their ability to provide stability and support (3).

Muscle Weakness and Muscle Imbalance

Muscle Weakness. Many conditions are characterized by **muscle weakness**. Some show definite patterns of muscle involvement; others show intermittent weakness without any apparent pattern. In some cases, weakness is symmetrical; in others, asymmetrical. The site or level of peripheral lesion may be determined because the muscles distal to the site of the lesion will show weakness or paralysis. Careful testing and accurate recording of test results will reveal the characteristic findings and aid in diagnosis.

Many factors influence weakness and the return of muscle strength. Weakness may be due to nerve involvement, disuse atrophy, stretch weakness, pain, or fatigue. Return of muscle strength may be due to recovery following a disease process, return of nerve impulse, after trauma and repair, hypertrophy of unaffected muscle fibers, muscular development resulting from exercises to overcome disuse atrophy, or return of strength after stretch and strain have been relieved.

Muscle weakness should be treated in accordance with the basic cause of weakness. If due to lack of use, then exercise; if due to overwork and fatigue, then rest; if due to stretch and strain, then relief of stretch and strain before the stress of additional exercise is thrust upon the weak muscle.

Muscle Imbalance. Conditions frequently show patterns of muscle imbalance. Some patterns are associated with handedness, some with habitually poor posture. Muscle imbalance may also result from occupational or recreational activities in which there is persistent use of certain muscles without adequate exercise of opposing muscles. Imbalance that affects postural alignment is an important factor in many painful conditions (4–6).

Muscle imbalance can distort postural alignment and set the stage for undue stress and strain on joints, ligaments, and muscles. Manual muscle testing is the tool of choice to determine the extent of imbalance.

Muscle Functions

Every muscle is a prime mover in some specific action. When any one muscle is paralyzed, stability of the adjacent joints and structures is impaired and normal movement is lost. Some of the most dramatic evidence of muscle function comes from observing the effects of loss of the ability to contract as seen in paralyzed muscles, or the effect of excessive shortening as seen in a muscle contracture and the resultant deformity.

The muscle testing described in this book is directed toward examination of individual muscles insofar as is practical. The overlap of muscle actions, as well as the interdependence of muscles in movement, is well recognized by those involved in muscle testing. Because of this close relationship in functions, accurate testing of individual muscles requires strict adherence to the fundamental principles of muscle testing and rules of procedure.

Fundamental components of manual muscle testing are test performance and evaluation of muscle strength and length. To become proficient in these procedures, one must possess a comprehensive and detailed knowledge of human anatomy and muscle function. This knowledge must include an understanding of joint motion because length and strength tests are described in terms of joint movements and positions. It must also include knowledge of muscular innervations, the agonistic and antagonistic actions of muscles, and their role in fixation and compensation. In addition, it requires the ability to palpate the muscle or its tendon, to distinguish between normal and atrophied contour, and to recognize abnormalities of position or movement.

Evidence-Based Objectivity and Reliability in Muscle Testing

Muscle testing measures must be objective. With the high cost of medical care, the economics of reimbursement requires documentation that treatment is necessary and improvement has resulted from treatment. The more gradual the improvement, the more important the numbers become so that even minimal changes can be documented.

Many advocate the use of instrumentation to eliminate the subjective component of manual muscle tests (7). How do new problems and variables introduced by instruments affect the accuracy, reliability, and validity of muscle tests? To date, the research is conflicting.

Instrumentation, Machines, and Devices

The value of objective measurements obtained using modern instrumentation must be weighed against their limited usefulness, cost, and complexity. Length tests, if performed with precision, can provide objective data using simple devices such as goniometers to measure angles and rulers or tape measures to measure distance. Strength tests cannot rely on these devices. Objectivity is based on the examiner's ability to palpate and observe the tendon or muscle response in very weak muscles. Additionally, an examiner can visualize a tendon that becomes prominent (i.e., a trace grade), movement of a segment in the horizontal plane (i.e., a poor grade), and a segment being held in an antigravity position (i.e., a fair grade). Even the fair+ grade, which is based on holding the antigravity position against slight pressure by the examiner, is easy to identify. For these grades of strength, mechanical devices are not applicable or necessary to ensure objectivity. However, instrumentation may play a role in the assessment of the muscle grades of good and normal as well as strength above normal.

Isokinetic Machines and Electromyography. Under controlled research conditions, isokinetic machines can help in obtaining valuable information. At present, however, their usefulness in the clinic is limited. Problems occur both in testing muscle strength and in exercising. One problem with machines is providing adequate stabilization to control variables and to ensure the standardization of testing techniques. Tests by machines lack specificity, and compensation occurs. In addition to the high cost of the machines, setting up patients is time-consuming; both are important factors when comparing cost-effectiveness of the testing procedures with that of skilled manual muscle testing.

Electromyography (EMG) is another important research tool, but its usefulness in muscle strength testing is questionable. According to Gregory Rash, "EMG data cannot tell us how strong the muscle is, if one muscle is stronger than another muscle, if the contraction is a concentric or eccentric contraction, or if the activity is under voluntary control by the individual" (8).

Handheld Devices. Handheld devices (HHDs), such as dynamometers, measure the amount of force exerted by the examiner and countered by the subject. HHDs are more readily available in today's clinics and provide objective data regarding the amount of force that is used during manual muscle strength testing. The problem with an HHD is that it comes between the examiner and the segment being tested. It also interferes with use of the examiner's hand. The examiner's hand must not be encumbered for positioning the segment, controlling the specific direction of pressure, or applying pressure with the fingers, palm, or whole hand as needed.

A review of the literature regarding dynamometers reveals some of the problems associated with the use of these devices. Reliability across testers, examiner strength, and gender differences have all been found to limit intertester reliability when using handheld dynamometry. A study of intertester reliability concluded that "the handheld dynamometer shows limited reliability when used by two or more testers" (9). Two studies have demonstrated good intratester reliability using handheld dynamometers (10, 11). However, "hand-held dynamometers … may underestimate a patient's true maximal isometric strength, due to difficulties in stabilization of the device" (12). Bohannon reports that although no formal determination of minimal clinically important difference has been described for handheld dynamometry, the report provided relevant information.

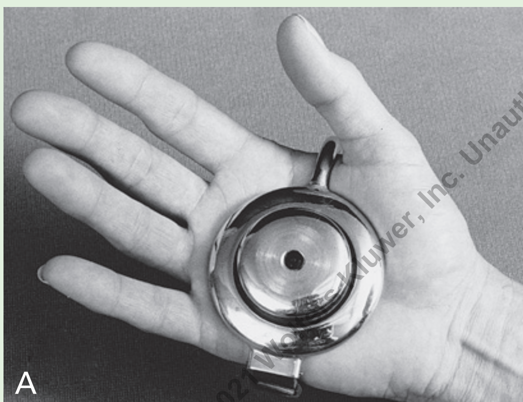
Examiner strength presents another variable in handheld dynamometer reliability. Work by Marino et al. identified examiner strength as the reason for discrepancy between two examiners testing hip abductor strength (13). The examiner's strength affects the stability of the handheld dynamometer when used with stronger subjects (11). This problem was also related to gender differences by Mulroy et al. The subject's maximal knee extension force, measured by a handheld dynamometer, was accurate only for the male examiner testing female patients (14). (The validity of measurements obtained by HHD, like the reliability of the measurements, is dependent on the tester having adequate strength to hold stably against the effort of the tested individual. Without such strength, the maximum force the tester can measure is limited by his or her own strength.)

Hands, the Preferred Tools of Measurement

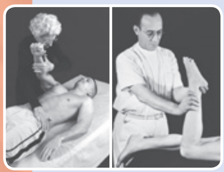
After a decade of scientific review, Newton and Waddell concluded that the "judgment of the clinician appears to be more accurate in determining effort of the patient, than evaluating the results from the machines" (15).

As tools, our hands are very sensitive, fine-tuned instruments. One hand of the examiner positions and stabilizes the segment adjacent to the segment being tested. The other hand determines the pain-free range of motion, guides the tested segment into precise test position, and gives the appropriate amount of pressure to determine strength. All the while, this instrument we call the hand is hooked up to the most marvelous computer ever created—the human mind—which can store valuable and useful information on the basis of which judgments about evaluation and treatment can be made. Such information contains objective data that are obtained without sacrificing the art and science of manual muscle testing to the demand for objectivity.

HISTORICAL NOTE



In 1941, while engaged in a research study for the Foundation for Infantile Paralysis, Florence Kendall designed an HHD to measure the force applied by the examiner during manual muscle testing. The Foundation turned over the design to Dr. W. Beasley in Washington, DC, who made a prototype. One year later, this device was presented at a symposium on polio. ***A*** shows the pressure-sensitive pad in the palm of the hand from which force was transmitted to the gauge on the dorsum of the hand, shown in ***B*** (Lippincott, Williams, & Wilkins, © Copyright 2005.) This may have been one of the first handheld dynamometers. ***C***. Modern manual muscle tester (C/O Lafayette Instrument Company, Inc.)



CLASSIC KENDALL

One of the unique features of this text is the preservation of more than half a century of postural analyses and the careful evaluation of muscle balance as it relates to function and pain. Many of the photographs provide outstanding historic examples of postural faults that are genuine rather than posed.

It is essential that every practitioner develop effective problem-solving skills that will result in choosing and performing appropriate and accurate tests to provide meaningful data for the establishment of a successful treatment plan. Anatomy has not changed, but time constraints in some current practice settings have resulted in testing "shortcuts" that can lead to an incorrect diagnosis.

The Kendalls were early pioneers in performing clinical research as part of their continual quest for knowledge regarding how muscle length and weakness relate to painful conditions. A study performed in the early 1950s compared hundreds of "normal" subjects—cadets, physicians, physical therapists, and student nurses (age range, 18–40 years)—with patients who had LBP. That study led to a better understanding of common muscle imbalances in the general population as compared to those in patients with LBP. In addition, it helped to define the differences in these imbalances between males and females. The data from this clinical study are included in the following table.

Male (% [*n*])				Female (% [*n*])		
100 LBP Patients	36 Physicians	275 Cadets	Case Findings	307 Student Nurses	50 Physical Therapists	100 LBP Patients
58% (58)	25% (9)	5% (14)	Weakness in "upper" anterior abdominals	44% (135)	52% (26)	81% (81)
69% (69)	31% (11)	33% (91)	Weakness in "lower" anterior abdominals	79% (243)	72% (36)	96% (96)
71% (71)	45% (16)	10% (28)	Limitation of forward flexion	5% (15)	10% (5)	48% (48)
71% (71)	77% (28)	26% (72)	Right gluteus medius weakness	40% (123)	76% (38)	90% (90)
15% (15)	3% (1)	5% (14)	Left gluteus medius weakness	5.5% (17)	10% (5)	6% (6)
0% (0)	0% (0)	0.3% (1)	Bilateral gluteus medius weakness	5.5% (17)	0% (0)	12% (12)

SECTION I
BODY SYSTEMS

POSITIONAL REFERENCE

Body Segments

Posture is a composite of the positions of all the joints of the body at any given moment, and static postural alignment is best described in terms of the positions of the various joints and body segments. This chapter provides basic information about anatomical positions, axes, planes, and movements of joints. This information is essential when analyzing postural alignment (Figure 1-1).

Anatomical Position

The anatomical position of the body is an erect posture with face forward, arms at sides, palms forward, and fingers and thumb in extension. This is the position of reference for definitions and descriptions of body planes and axes (Figure 1-2).

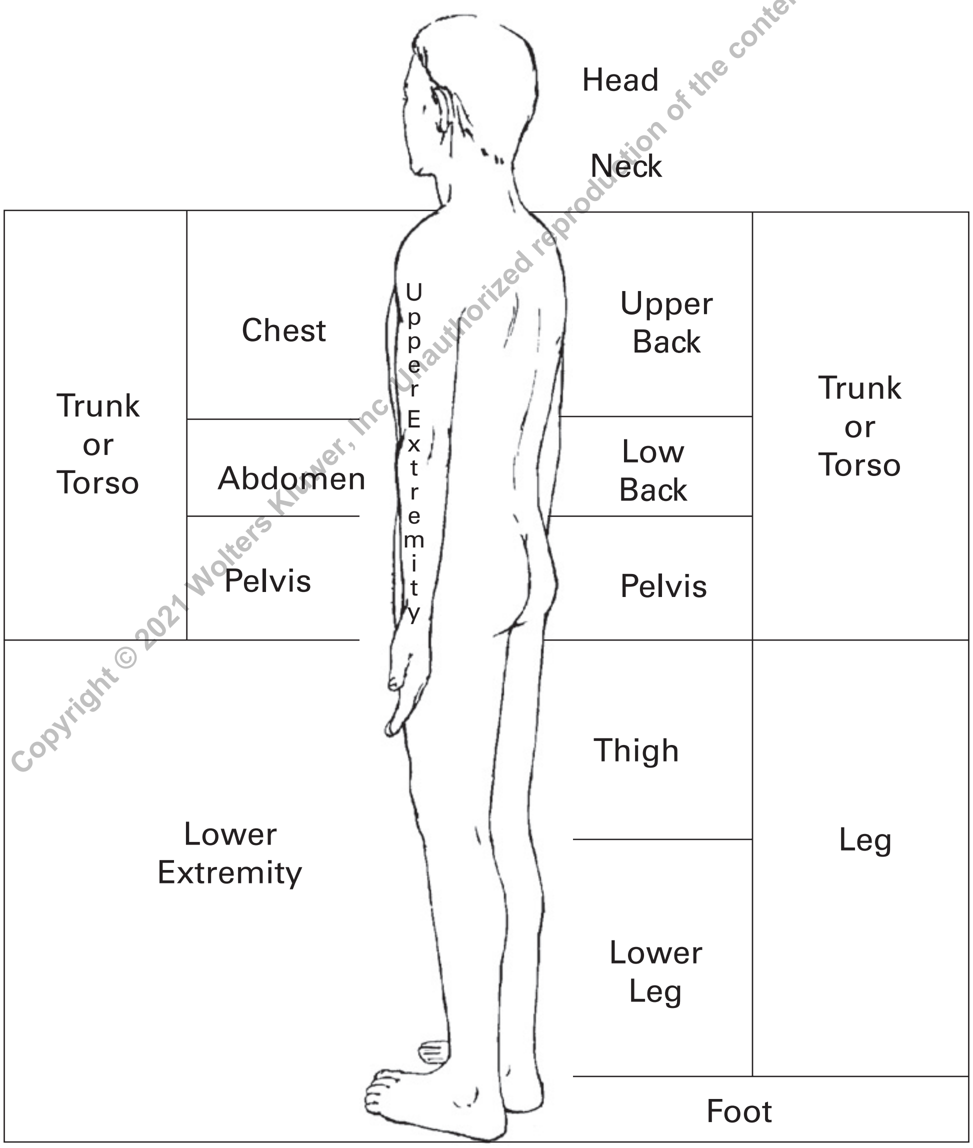


FIGURE 1-1: Common terminology to describe anatomical positions, axes, planes, and movements of joints.

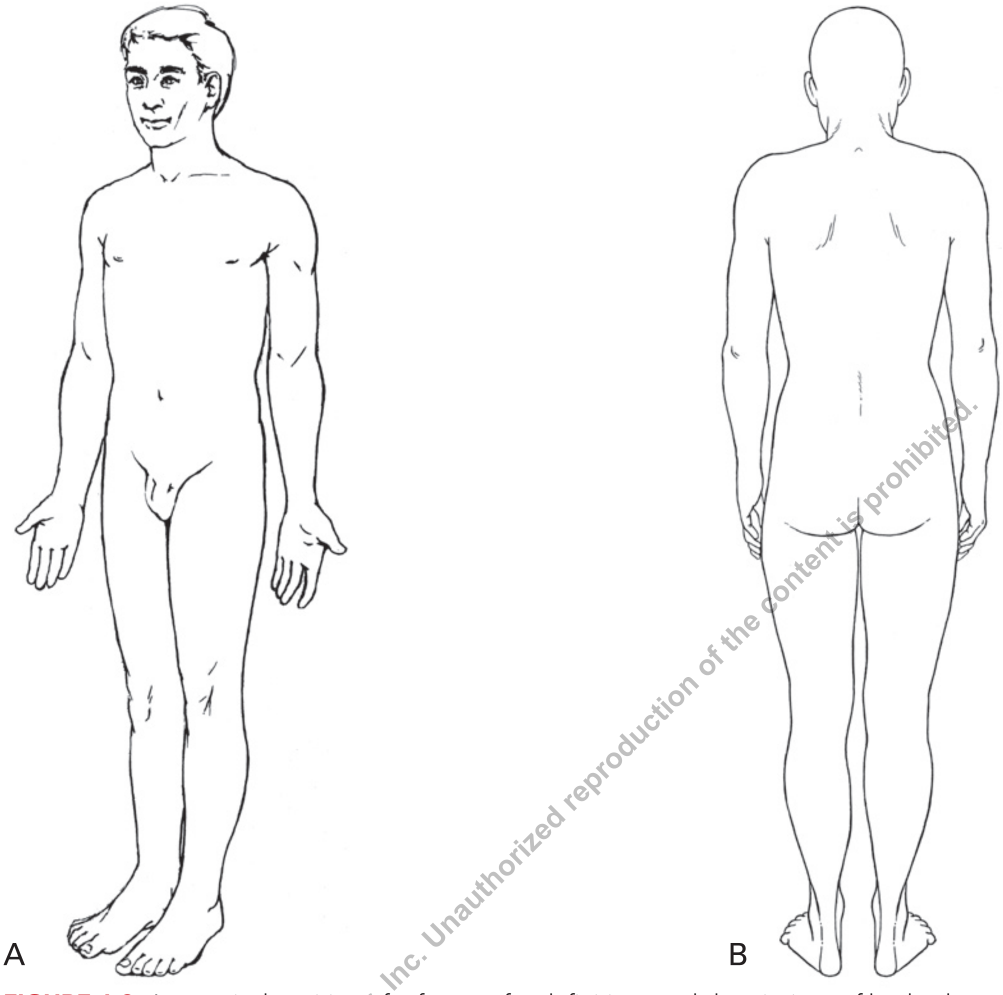


FIGURE 1-2: Anatomical position of reference for definitions and descriptions of body planes and axes: **A**, Front; **B**, Zero position (back).

Axes

Axes are lines, real or imaginary, about which movement takes place. Related to the planes of reference seen in the following text are three basic types of axes at right angles to each other (16):

1. A *sagittal (anterior–posterior) axis* lies in the sagittal plane and extends horizontally from front to back. The movements of abduction and adduction take place about this axis in a coronal plane.
2. A *coronal (medial–lateral) axis* lies in the coronal plane and extends horizontally from side to side. The movements of flexion and extension take place about this axis in a sagittal plane.
3. A *longitudinal (vertical or superior–inferior) axis* extends in a cranial-caudal direction. The movements of medial and lateral rotation take place about this axis in a transverse plane.

Exceptions to these general definitions occur with respect to movements of the scapula, clavicle, and thumb.

Planes

The three basic planes of reference are derived from the dimensions in space and are at right angles to each other (Figure 1-3) (16):

1. A *sagittal plane* is vertical and extends from front to back, deriving its name from the direction of the sagittal suture of the skull. It may also be called an antero-posterior plane. The median sagittal plane, or *midsagittal*, divides the body into right and left portions.
2. A *coronal plane* is vertical and extends from side to side, deriving its name from the direction of the coronal suture of the skull. It is also called the frontal or lateral plane, and it divides the body into an anterior and a posterior portion.
3. A *transverse plane* is horizontal and divides the body into upper (cranial) and lower (caudal) portions.

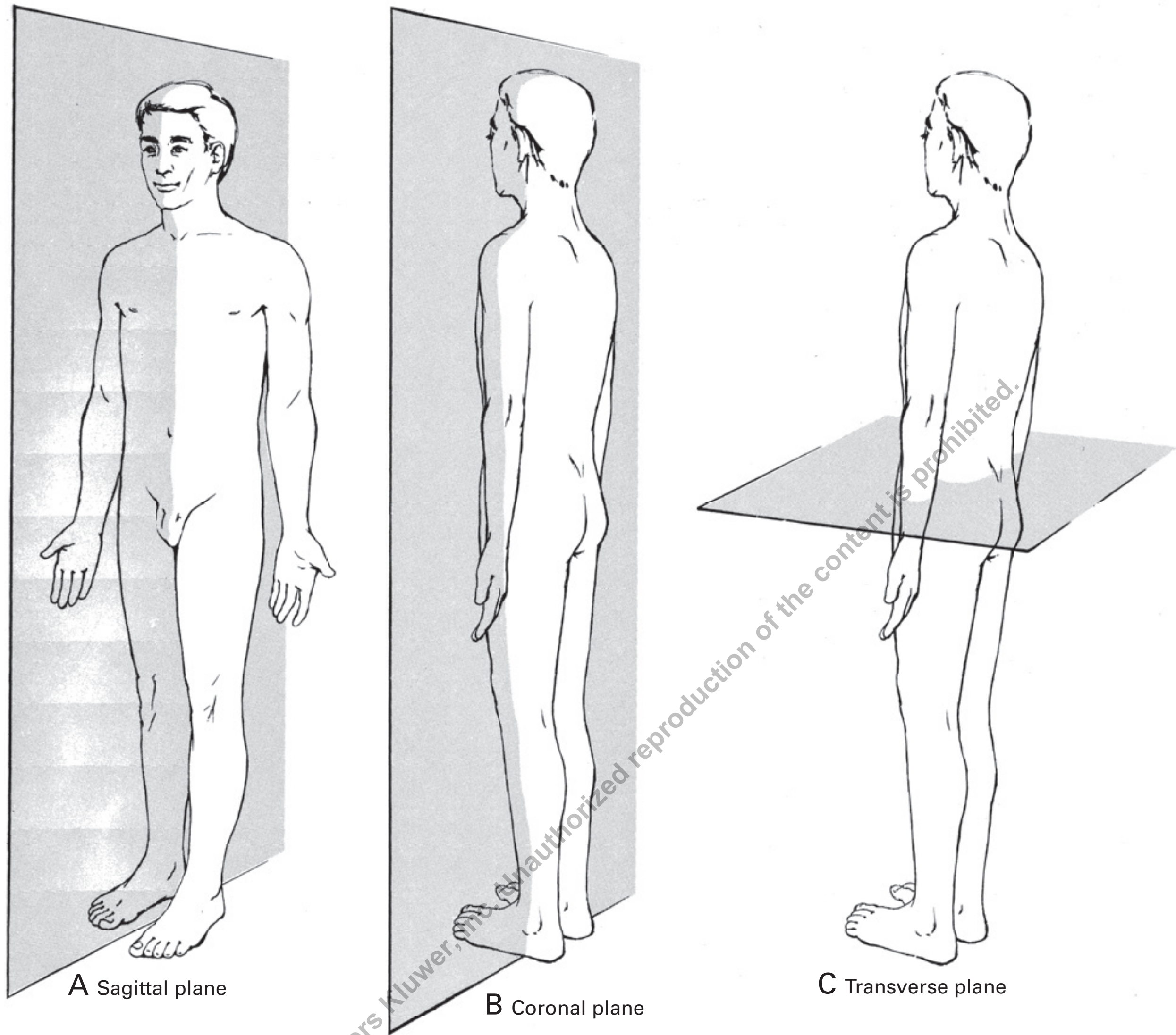


FIGURE 1-3: Three basic planes of reference: **A**, Sagittal; **B**, Coronal; **C**, Transverse.

Movements

Movements in the Coronal Plane

Movements of abduction, adduction, and lateral flexion occur within the coronal plane about a sagittal axis. The sagittal axis is positioned at a right angle to the coronal plane.

Abduction and Adduction. Abduction is movement away from and adduction is movement toward the mid-sagittal plane of the body for all joints of the extremities except the thumb, fingers, and toes (Figures 1-4 and 1-5) (16). The movements of the thumb are referenced to the plane of the palm of the hand. Abduction and adduction of digits 2–5 are movements away from and toward the axial line that extends through the third digit. For the toes, the axial line extends through the second digit.

Lateral Flexion. Lateral flexion denotes abduction and adduction movement dedicated to the spine, resulting in positional changes of the head, neck, and trunk.

Movements in the Sagittal Plane

Movements of flexion and extension occur within the sagittal plane about a coronal axis. The coronal axis is positioned at a right angle to the sagittal plane.

Flexion and Extension. At an early stage, the limbs of the embryo are directed ventrally, the flexor surfaces medially, and the great toes and thumbs cranially. With further development, the limbs rotate 90° at their girdle articulation so that the thumbs turn laterally and the flexor surfaces of the upper extremities ventrally, while the great toes turn medially and the flexor surfaces of the lower extremities dorsally. As a result of this 90° rotation of the limbs in opposite directions, movement that approximates

FIGURE 1-4: The body bending within the coronal plane.

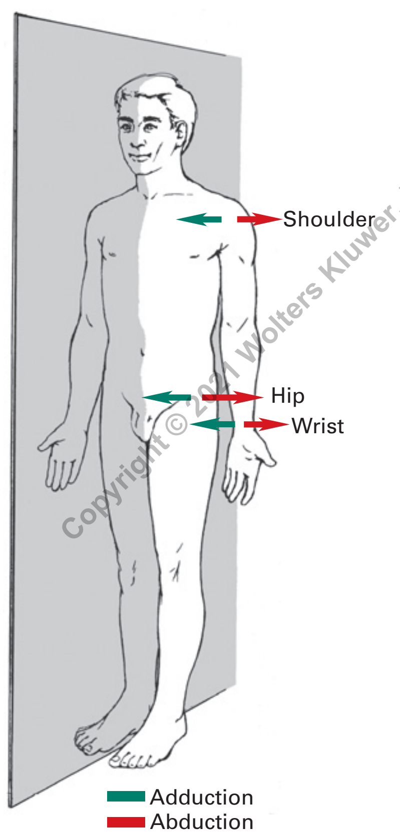


FIGURE 1-5: Points of abduction and adduction on the body within the sagittal plane.

the hand and the anterior surface of the forearm is termed flexion, because it is performed by flexor muscles. Movement that approximates the foot and anterior surface of the leg is termed extension, because it is performed by extensor muscles. See Figures 1-6 and 1-7.

Flexion is the movement of bending forward (i.e., in an anterior direction) for joints of the spine, upper extremity, and hip, and movement in the posterior direction for the knee, ankle, and joints of the toes.

Extension is movement in the direction opposite to flexion (i.e., in a posterior direction) for the joints of the spine, upper extremity, and hip, and movements in an anterior direction for the knee, ankle, and joints of the toes, returning the body to the anatomical position. The difference occurs because the developmental pattern of the lower extremities differs from that of the upper extremities.

Hyperextension is the term used to describe excessive movement in the direction of extension, as in hyperextension of the knees. It is also used in reference to the increased lumbar curvature as in a hyperlordosis with anterior pelvic tilt, or an increased cervical curvature as in a forward head position. In such instances, the range of motion through which the lumbar or cervical spine moves is not excessive, but the position of extension is greater than desirable from a postural standpoint.

FIGURE 1-6: The body bending within the sagittal plane.

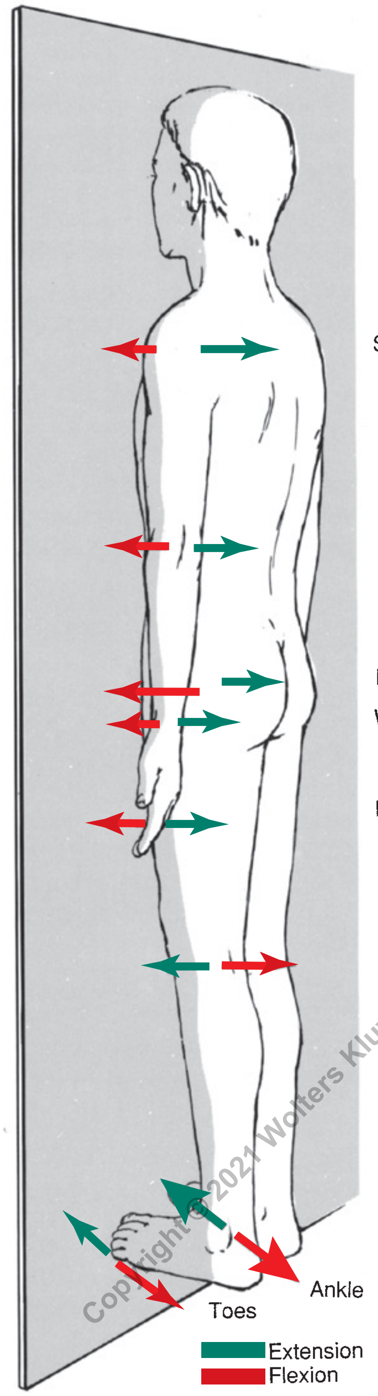


FIGURE 1-7: Points of flexion and extension on the body within the coronal plane.

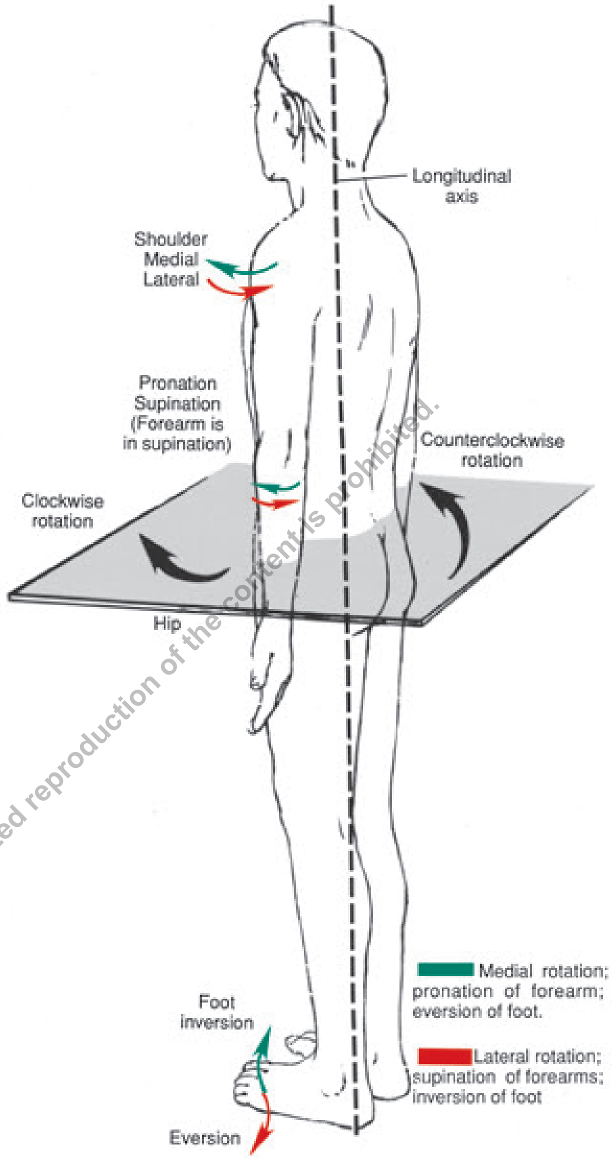


FIGURE 1-8: Points of rotation about a longitudinal axis within a transverse plane.

Movements in the Transverse Plane

Rotation. Rotation refers to movement around a longitudinal axis, in a transverse plane, for all areas of the body except the scapula and clavicle. A *longitudinal* axis is vertical, extending in a cranial-caudal direction.

In the extremities, rotation occurs about the anatomical axis except in the case of the femur, which rotates about a mechanical axis. In the extremities, the anterior surface of the extremity is used as a reference area. Rotation of the anterior surface toward the midsagittal plane of the body is *medial* rotation, and that away from the midsagittal plane is *lateral* rotation (Figure 1-8).

Because the head, neck, thorax, and pelvis rotate about longitudinal axes in the midsagittal area, rotation cannot be named in reference to the midsagittal plane. Rotation of the head and thorax is described as right or left rotation. Rotation of the pelvis may also be described as clockwise or counterclockwise. With the transverse plane as a reference and 12 o'clock at midpoint anteriorly, *clockwise* rotation occurs when the left side of the thorax or pelvis is more forward than the right, and *counterclockwise* rotation occurs when the right side is more forward.

Tilt. Tilt describes certain movements of the scapula and pelvis. The pelvis may tilt in an anterior or posterior direction about a coronal axis. Anterior tilt of the pelvis results in extension of the lumbar spine and posterior tilt results in flexion (flattening) of the lumbar spine.

The pelvis may also tilt laterally, moving about a sagittal axis. Lateral tilt of the pelvis is termed high on one side or low on the other and will be accompanied by lateral flexion of the lumbar spine to either the ipsilateral or contralateral side.

Because the pelvis moves at times as a unit, a tilt may be viewed as an anterior, posterior, or lateral tilt. An anterior or posterior tilt would occur in the sagittal plane and a lateral tilt would occur in the coronal plane. Rotation of the pelvis would occur in the transverse plane as seen in Figure 1-8.

With the scapula in a neutral position, there may be anterior tilt but not posterior tilt, except that return from anterior tilt may be referred to as such.

Combination Movements

Circumduction. Circumduction is a movement that successively combines flexion, abduction, extension, and adduction in which the segment being moved describes a cone. The proximal end of the extremity forms the apex of the cone, serving as a pivot, and the distal end circumscribes a circle. Such movements are possible only in ball-and-socket, condyloid, and saddle type joints.

MUSCULOSKELETAL SYSTEM

The musculoskeletal system is composed of striated **muscles**, various types of **connective tissues**, and the **skeleton**. This system provides the essential components for strength, flexibility, and stability in weight bearing.

The bones of the skeleton are joined together by **ligaments**, which are strong, fibrous bands (sheets) of connective tissue. They are flexible but not extensible. Some ligaments limit motion to such an extent that the joint is immovable; some allow freedom of movement. Ligaments are classified as **capsular**, **extracapsular**, and **intracapsular**. They contain nerve endings that are important in reflex mechanisms and in the perception of movement and position. Ligaments may differ from the standpoint of mechanical function. For example, a collateral ligament is an extracapsular type that remains taut throughout the range of joint motion, whereas a cruciate ligament (as in the knee joint) becomes slack during some movements and taut during others.

Skeletal muscle fibers are classified primarily into two types: type I (red slow twitch) and type II (white fast twitch). The two types of fibers are intermingled in most muscles. Usually, however, one type predominates, with the predominant type depending on the contractile properties of the muscle as a whole. Type I fibers seem to predominate in some postural muscles, such as the erector spinae and soleus. Type II fibers often predominate in limb muscles, where rapid, powerful forces are needed. Variability does occur, however, in these ratios in the population, especially as related to development and aging. Skeletal muscles constitute approximately 40% of body weight and are attached to the skeleton by aponeuroses, fasciae, or tendons.

Aponeuroses are sheets of dense connective tissue and are glistening white in color. They furnish the broad origins for the latissimus dorsi muscles. The external and internal oblique muscles are attached to the linea alba by means of aponeuroses. The palmaris longus inserts into and tenses the palmar aponeurosis.

Fascia is of two types: **superficial**, which lies beneath the skin and permits free movement of the skin, and **deep**, which envelopes, invests, and separates muscles. Some deep fasciae furnish attachments for muscles. For example, the iliotibial tract is a strong band of deep fasciae that provides attachments for the tensor fasciae latae into the tibia and for the gluteus maximus into the femur and tibia. The thoracolumbar fascia furnishes attachment for the transversus abdominis.

Tendons are white, fibrous bands that attach muscles to bones. They have great tensile strength but are practically inelastic and resistant to stretch. Tendons have few blood vessels but are supplied with sensory nerve fibers that terminate in organs of Golgi near the musculotendinous junction. In injuries that involve a severe stretch, the muscle most likely is affected, and sometimes the tendinous attachment to the bone is affected. For example, the peroneus brevis attachment at the base of the fifth metatarsal may be disrupted in an inversion injury of the foot. Tendons can also rupture. When the Achilles tendon ruptures, there is retraction of the gastrocnemius and soleus muscles with spasm and acute pain.

Joints: Definitions and Classification

A **joint** is defined as a union or junction between two or more bones and can be classified into three general morphologic types: fibrous joints, cartilaginous joints, and synovial joints (17, 18). Joints are supported by fibrous, cartilaginous, or synovial tissue and are typically named according to the bones that comprise the given articulation.

For some joints, the bones are held so close together that no appreciable motion occurs. They provide great stability. Some joints provide stability in one direction and freedom of motion in the opposite direction, and some provide freedom of motion in all directions.

Joints that provide little or no movement are those that hold the two sides of the body together. The sagittal suture of the skull is considered to be an immovable joint, held together by a strong fibrous membrane. The symphysis pubis is considered to be slightly movable and is held together by strong **fibrocartilaginous** membranes.

TABLE 1-1 Classification of Joints

Tissue	Joint		Movement	Example
Fibrous	Synarthrosis	Syndesmosis	Immovable	Tibiofibular (distal)
		Sutura	Immovable	Suture of skull
		Gomphosis	Immovable	Tooth in bony socket
Cartilaginous	Amphiarthrosis	Synchondrosis	Slightly movable	First sternocostal
		Symphysis	Slightly movable	Symphysis pubis
Synovial	Diarthrosis	Spheroid or ball-and-socket	All joint movements	Shoulder (2) and hip
		Ginglymus	Flexion and extension	Elbow
		Modified ginglymus	Flexion, extension, and slight rotation	Knee and ankle
		Ellipsoid or condyloid	All except rotation and opposition	Metacarpopha-langeal and metatar-sophalangeal
		Trochoid or pivot	Supination, pronation, and rotation	Atlantoaxial and radioulnar
		Reciprocal-reception or saddle	All except rotation	Calcaneocuboid and carpometacarpal
		Plane or gliding	Gliding	Head of fibula with lateral condyle of tibia
		Combined ginglymus and gliding	Flexion, extension, and gliding	Temporomandibular

Most joints fall into the category of freely movable joints held together by synovial membranes. The elbow and knee joints are essentially hinge joints. The structure of the joint surfaces and the strong lateral and medial ligaments limit sideways movements, and anterior (elbow) and posterior (knee) ligaments and muscles limit extension. Hence, there is stability and strength in the extended position. In contrast, the shoulder joints are movable in all directions and have less stability (Table 1-1).

Gross Structure of Muscle

The gross structure of muscle helps to determine muscle action and affects the way that a muscle responds to stretching. Muscle fibers are arranged in bundles called **fasciculi**. The arrangement of fasciculi and their attachments to tendons varies structurally. Two main divisions are found in gross structure: fusiform (or spindle) and pennate. A third arrangement, fan-shaped, is probably a modification of the other two but has a distinct clinical significance. See Figure 1-9 A–C.

Fusiform fibers are arranged essentially parallel to the line from origin to insertion and the fasciculi terminate at both ends of the muscle in flat tendons. **Pennate** fibers are inserted obliquely into the tendon or tendons that extend the length of the muscle on one side (i.e., unipennate) or through the belly of the muscle (i.e., bipennate).

Other structural examples include flat (external abdominal oblique, e.g.), circular (orbicularis oculi, e.g.), quadrate (quadratus femoris, e.g.), and multihead/bellied (biceps brachii).

In all probability, the long fusiform muscle is the most vulnerable to stretch. The joint motion is in the same direction as the length of the fiber, and each longitudinal component is dependent on every other one. The pennate muscles are probably the least vulnerable to stretch, both because the muscle fiber is oblique to the direction of joint motion and because the fibers and fasciculi are short and parallel and, thereby, are not dependent on other segments for continuity in action.

The fan-shaped muscle has advantages and disadvantages of the fusiform and the pennate muscles. It might be thought of as a group of muscles arranged side by side to form a fan-shaped unit. Each segment is independent in that it has its own origin with a common insertion. For example, in the fan-shaped pectoralis major, the clavicular part may be unaffected but the sternal part paralyzed in a spinal cord lesion.

According to *Gray's Anatomy,* the "arrangement of fasciculi is correlated with the power of the muscles. Those with comparatively few fasciculi, extending the length of the muscle, have a greater range of motion but not as much power. Penniform muscles, with a large number of fasciculi distributed along their tendons, have greater power but smaller range of motion" (17).

Types of Muscle Contraction

All types of contractions will be utilized throughout the procedures of manual muscle testing. Understanding the normal tonic phase of muscle and muscle groups will be useful during the posture screen and evaluation. The *tonic* phase of muscle refers to its resting state. During this phase it is stated that muscle rests in a slight state of contraction.

Phasic contractions of muscle include *isotonic* and *isometric* contractions. **Isotonic** muscle contractions involve a

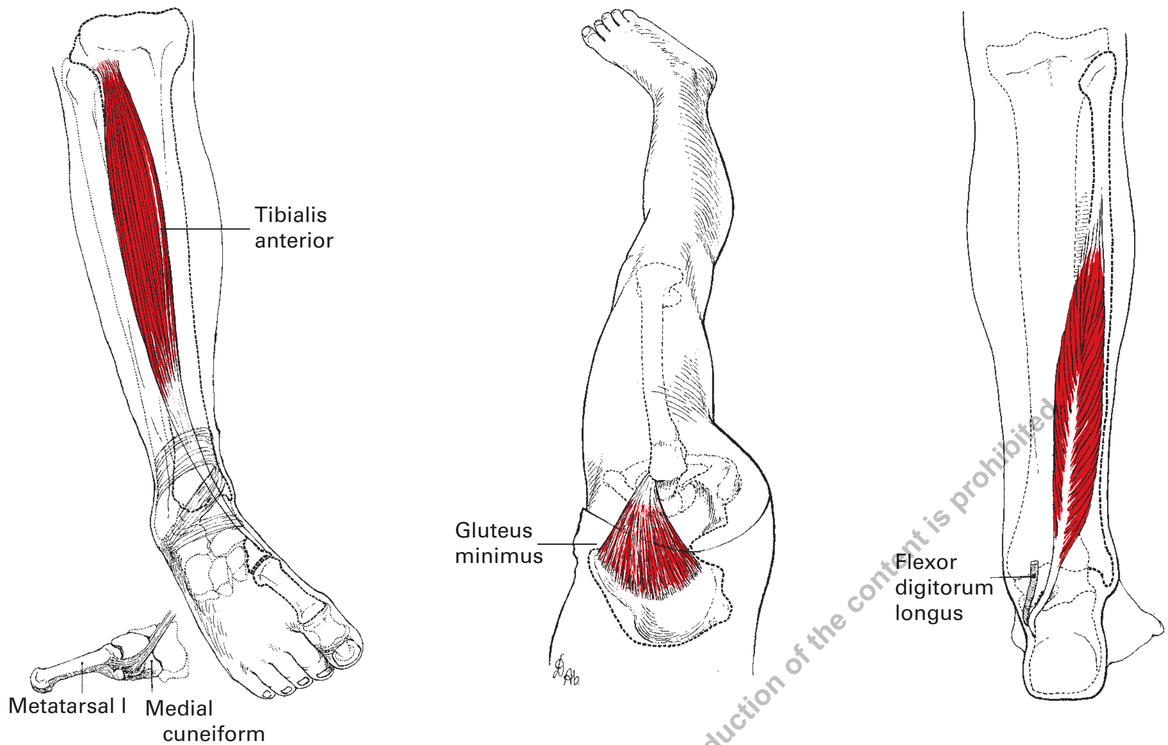


FIGURE 1-9: Gross structure of muscles: **A**, Fusiform; **B**, Fan-shaped; **C**, Pennate.

change in length of muscle that results in an action about a given joint, thus producing movement. An **isometric** contraction involves little to no change in the length of muscle that typically does not generate an action about a given joint, therefore does not produce movement. During functional tasks, muscle actions will produce movement by transitioning through these phases utilizing each type of contraction in an orchestrated fashion to complete a given task.

NERVOUS SYSTEM

Nervous system function is imperative for the control and activation of muscles allowing for the independent completion of task performance. The nervous system detects internal and external environmental changes that impact the body, then works in tandem with other systems to respond accordingly (18, 19).

The nervous system is composed of two primary divisions: the central nervous system (CNS) and the peripheral nervous system (PNS). Subdivisions of the PNS include the somatic, autonomic, and enteric systems. The former two will be discussed in brief detail below.

The somatic nervous system is considered to be a voluntary system that allows for conscious control of movement. Motor neurons innervate skeletal muscle and sensory neurons provide feedback from the environment through receptors in the skin, tendons, and joints via feedback and feedforward mechanisms.

The autonomic nervous motor system is an involuntary system that mitigates visceral function. Motor neurons innervate cardiac muscle, smooth muscle found in glands, blood vessels, and other organs of the body. The autonomic system is further divided into parasympathetic and sympathetic systems. The parasympathetic system is responsible for the maintenance of or return to a level of homeostasis while the sympathetic system activates in response to stress.

This text will focus on the transition of the CNS to the PNS and their integration with muscle function. Types of peripheral nerves include the spinal nerves and the cranial nerves.

Spinal Nerves

There are 31 pairs of **spinal nerves**. Spinal nerves are mixed nerves that originate from the spinal cord. Each of the 31 pairs of spinal nerves arises from the spinal cord by two spinal **nerve roots**. The **ventral root** is composed of motor neurons and the **dorsal root** is composed of sensory neurons. These nerve roots unite as they approach the intervertebral foramen to form the spinal nerve. A spinal **segment** is the component of the spinal cord that gives rise to each pair of spinal nerves. Each spinal nerve contains motor and sensory fibers numbered from a single spinal segment.

Shortly after the spinal nerve exits through the foramen, it divides into a **dorsal primary ramus** and a **ventral primary ramus.** The dorsal rami are directed posteriorly, and the sensory and motor fibers innervate the skin and extensor muscles of the neck and trunk. The ventral rami, except those in the thoracic region, contain the nerve fibers that form the plexuses.

Nerve Plexuses: Definitions

The term **plexus** comes from the Latin word plectere meaning braid. A **nerve plexus** results from the dividing, reuniting, and intertwining of nerves into a complex network. When describing the origins, components, and terminal branches of a plexus, the terms **nerves, roots,** and **cord** are used with dual meanings. There are spinal nerves and peripheral nerves, roots of the spinal nerves and roots of the plexus, and the spinal cord and cords of the plexus. To avoid confusion, appropriate modifying words are used in the descriptions that follow.

Plexus illustrations have been included with the appropriate chapters: cervical with neck, brachial with upper extremity, and both lumbar and sacral with lower extremity. Trunk muscles receive innervation directly from the thoracic nerves, plus a branch from the lumbar plexus.

Peripheral nerves emerge from the plexuses at various regions of the plexus with terminal branches extending from the medial, lateral, and posterior cords. As a result of the interchange of fibers within the plexus, peripheral nerves contain fibers from at least two and, in some instances, as many as five spinal segments.

The **spinal cord** lies within the vertebral column, extending from the first cervical vertebra to the level of the second lumbar vertebra.

Segmental Distributions

For anatomists and clinicians, the determination of spinal segment distribution to peripheral nerves and muscles has proven to be a difficult task. The pathway of the spinal nerves is obscured by the intertwining of the nerve fibers as they pass through the nerve plexuses. Since it is almost impossible to trace the course of an individual nerve fiber through the maze of its plexus, information regarding spinal segment distribution has been derived mainly from clinical observation. The use of this empirical method has resulted in a variety of findings regarding the segmental origins of these nerves and the muscles they innervate. An awareness of possible variations is important in the diagnosis and the location of a nerve lesion. To focus attention on the range of variations that exists, the Kendalls tabulated information from six well-known sources. (Please see the series of charts in Appendix D.)

OTHER BODY SYSTEMS

While the musculoskeletal and nervous systems are the primary focus of manual muscle testing and postural evaluations, an astute clinician recognizes that other systems play roles in normal muscle function. These systems include the circulatory, respiratory, integumentary, digestive, lymphatic, endocrine, and renal systems. Table 1-2 provides limited examples of how these systems can impact muscle function.

TABLE 1-2 Body Systems and Their Impact on Muscle Function

System	Components	Potential Impact on Muscle Function	Presentation
Circulatory	Heart, great vessels, arteries, veins, capillaries	Decreased nutrition, metabolite evacuation and O_2 supply contracted state decreases blood flow	Decreased strength, atrophy, pain
Respiratory	Lungs, airway, pulmonary vessels	Decrease in O_2 supply, limit of CO_2 evacuation	Decreased strength, atrophy, pain
Integumentary	Skin, hair	Scarring	Limit available range of motion
Digestive	Alimentary canal	Decreased nutrition, impaired glycogen storage in muscle	Decreased strength, fatigue
Renal	Kidneys, bladder, ureters, urethra	Edema, increased weight of extremity	Edema
Lymphatic	Lymph vessels, glands, spleen	Edema, increased weight of extremity	Edema
Endocrine	Pancreas, thyroid, adrenal glands	Change in blood sugar, decreased glycogen storage in muscle, hypo/hyperthyroid myopathies, proximal muscle weakness/wasting in Cushing syndrome, etc.	Decreased muscle strength, atrophy, decreased coordination

SECTION II
MANUAL TESTING (PROCEDURE, OBJECTIVITY, GRADING)

MUSCLE STRENGTH TESTS

Kendall Classification for Muscles

Test for Strength

Class I. One-joint muscles that actively shorten (i.e., concentric contraction) through range to completion of joint motion and exhibit maximal strength at completion of range (i.e., short and strong).

Examples: Triceps, medial and lateral heads; deltoid; pectoralis major; three one-joint thumb muscles; gluteus maximus; iliopsoas; and soleus.

Class II. Two-joint and multi-joint muscles that act like one-joint muscles by actively shortening over both or all joints simultaneously and exhibiting maximal strength at completion of range (i.e., short and strong).

Examples: Sartorius, tibialis anterior and posterior, and peroneus longus, brevis, and tertius.

Class III. Two-joint muscles that shorten over one-joint and lengthen over the other to provide midrange of the overall muscle length for maximal contraction and strength (as represented by the length–tension curve).

Examples: Rectus femoris, hamstrings, and gastrocnemius.

Class IV. Two-joint or multi-joint muscles that physiologically act in one direction but are prevented from overshortening by the coordinated action of synergic muscles.

Example of Two-Joint Muscle: The biceps act to flex the shoulder joint and the elbow joint. If acting to flex both joints simultaneously, the muscle would become overshortened. To prevent this, the shoulder extensors, as synergists, extend the shoulder joint, thereby lengthening the biceps over the shoulder joint when the elbow is maximally flexed by the biceps.

Example of Multi-Joint Muscle: If acting in one direction by flexing the wrists and fingers simultaneously, the finger flexors and extensors would overshorten and become actively insufficient. Nature, however, prevents this from happening. In forceful flexion of fingers, such as when making a fist, the flexors shorten over the finger joints but are prevented from shortening over their entire length by the synergic action of wrist extensors that hold the wrist in moderate extension, thereby lengthening the flexors over wrist joint for them to forcefully shorten over the finger joints.

Passive Insufficiency

As defined by O'Connell and Gardner:

> Passive insufficiency of a muscle is indicated whenever a full range of motion of any joint or joints that the muscle crosses is limited by that muscle's length, rather than by the arrangement of ligaments or structures of the joint itself (20).

As defined by Kendall:

> Passive insufficiency. Shortness of a two-joint (or multi-joint) muscle; the length of the muscle is not sufficient to permit *normal elongation* over both joints simultaneously, e.g., short hamstrings.

NOTE: *By both definitions, the term **passive insufficiency** refers to lack of muscle length. In contrast, the term **active insufficiency** refers to lack of muscle strength.*

Active Insufficiency

As defined by O'Connell and Gardner:

> If a muscle which crosses two or more joints produces simultaneous movement at all of the joints that it crosses, it soon reaches a length at which it can no longer generate a useful amount of force. Under these conditions, the muscle is said to be *actively insufficient.* An example of such insufficiency occurs when one tries to achieve full hip extension with maximal knee flexion. The two-joint hamstrings are incapable of shortening sufficiently to produce a complete range of motion of both joints simultaneously (20).

As defined by Kendall:

> Active insufficiency. The inability of a Class III or IV two-joint (or multi-joint) muscle to generate an effective force when placed in a fully shortened position. The same meaning is implied by the expression "the muscle has been put on a slack".

The two definitions above only apply to two-joint or multi-joint muscles. However, the statement that one-joint muscles exhibit their greatest strength at completion of range of motion has appeared in all five editions of Kendall's *Muscles: Testing and Function.* Knowing where the muscle exhibits its greatest strength in relation to the range of motion is of utmost importance for determining test position. After careful analysis, it is evident that there are four classifications.

Strength Testing Procedures

The order in which muscles are tested is largely a matter of choice, but it generally is arranged to avoid frequent and unnecessary changes of position for the subject (Box 1-1). Muscles that are closely related in position or action tend to appear in a testing order in sequence in order to distinguish test differences. *As a general rule, length testing precedes strength testing.* When the specific order of tests is important, it is so indicated in the text.

Terms Used in Description of Muscle Strength Tests

Descriptions of the muscle tests in Chapters 4 through 7 are presented under the headings of *Patient*, *Fixation*, *Test*, and *Pressure.* This chapter discusses each of these topics in detail to point out its particular significance in relation to accurate muscle testing.

Patient

In the description of each muscle test, this heading is followed by the position in which the patient is placed to accomplish the desired test. The position is important in relation to the test in two respects. First, insofar as is practical, the position of the body should permit function against gravity for all muscles in which gravity is a factor in grading. Second, the body should be placed in such a position that the segments not being tested will remain as stable as possible. (This point is discussed further under *Fixation.*)

In all muscle testing, the comfort of the patient and the intelligent handling of affected muscles are important factors. In some instances, the comfort of the patient or the condition of the affected muscles will necessitate some modification of the test position. For example, insisting on an antigravity position may result in absurd positioning of a patient. Side-lying, which offers the best test position for several muscles, may be uncomfortable and result in strain of other muscles.

Fixation

This heading refers to the stability of the body or body part, which is necessary to insure an accurate test of a muscle or muscle group. Stabilization (i.e., holding steady or holding down), support (i.e., holding up), and counterpressure (i.e., equal and opposite pressure) are all included under fixation. Fixation will be influenced by the firmness of the table, body weight of the patient, positioning and technique/skill of the clinician, and in some tests, the muscles that furnish fixation.

Adequate fixation depends to a great extent on the positioning of the patient and firmness of the examining table, which offers much of the necessary support. Testing and grading of strength will not be accurate if the table on which the patient lies has a thick, soft pad or soft mattress that "gives" as the examiner applies pressure.

Body weight may furnish the necessary fixation. Because the weight of the body is an important factor in

BOX 1-1

Basic Rules of Procedure That Apply to Muscle Strength Testing

1. Place the subject in a position that offers the best fixation of the body as a whole (usually supine, prone, or side-lying).
2. Stabilize the segment proximal to the tested segment or, as in the case of the hand, adjacent to the tested segment. Stabilization is necessary for specificity in testing.
3. Place the segment to be tested in precise antigravity test position, whenever appropriate, to help elicit the desired muscle action and aid in grading.
4. Use test movements in the horizontal plane when testing muscles that are too weak to function against gravity. Use test movements in antigravity positions for most trunk muscle tests in which body weight offers sufficient resistance.
5. Apply pressure directly opposite to the line of pull of the muscle or the muscle segment being tested. Like the antigravity position, the direction of pressure helps to elicit the desired muscle action.
6. Apply pressure gradually but not too slowly, allowing the subject to "get set and hold." Apply uniform pressure; avoid localized pressure that can cause discomfort.
7. Use a long lever whenever possible, unless contraindicated. The length of the lever is determined by the location of the pressure along the lever arm. Better discrimination of strength for purposes of grading is obtained through use of a long lever.
8. Use a short lever if the intervening muscles do not provide sufficient fixation for use of a long lever.

offering stability, the horizontal position, whether supine, prone, or side-lying, offers the best fixation for most tests. In the extremities, the body segment that is proximal to the tested segment must be stable.

The examiner may stabilize the proximal segments in tests of finger, wrist, toe, and foot muscles, but in other tests the body weight should help to stabilize the proximal segment. In some instances, the examiner may offer fixation in addition to the weight of the proximal segment. There may be a need to hold a segment firmly down on the table so that the pressure applied on the distal segment (plus the weight of that segment) does not displace the weight of the proximal segment. In rotation tests, it is necessary for the examiner to apply counterpressure to ensure exact test performance.

In some tests, muscles furnish fixation. The muscles that furnish fixation do not cross the same joint or joints as the muscle being tested. The muscles that stabilize the scapula during arm movements and the pelvis during leg movements are referred to as **fixation muscles.** They do not enter directly into the test movement, but they do stabilize the movable scapula to the trunk or the pelvis to the thorax and, thereby, make it possible for the tested muscle to have a firm origin from which to pull. In the same way, anterior abdominal muscles fix the thorax to the pelvis as anterior neck flexors act to lift the head forward in flexion from a supine position.

Muscles that have an antagonistic action give fixation by preventing excessive joint movement. This principle is illustrated by the fixation that the lumbricals and interossei provide in restricting hyperextension at the metacarpophalangeal joint during finger extension. In the presence of weak lumbricals and interossei, the pull of a strong extensor digitorum results in hyperextension of these joints and passive flexion of the interphalangeal joints. This hyperextension does not occur, however, and the fingers can be extended normally if the examiner prevents hyperextension of the metacarpophalangeal joints by fixation equivalent to that of the lumbricals and interossei.

When the fixation muscles are either too weak or too strong, the examiner can simulate the normal stabilization by assisting or restricting movement of the segment in question. The examiner must be able to differentiate between the normal action of these muscles in fixation and the abnormal actions that occur when compensation or muscle imbalance is present.

Test

In muscle testing, weakness must be distinguished from restriction of range of motion. Frequently, a muscle cannot complete the normal range of joint motion. It may be that the muscle is too weak to complete the movement, or it may be that the range of motion is restricted because of shortness of the muscles, capsule, or ligamentous structures. The examiner should passively carry the segment through the range of motion to determine whether any restriction exists. If no restriction is present, then failure by the subject to hold the test position may be interpreted as weakness unless joint or tendon laxity is present.

When testing one-joint muscles in which the ability to hold the segment at completion of range of motion is expected, the examiner must distinguish between muscle weakness and tendon insufficiency. For example, the quadriceps may be strong but unable to fully extend the knee because the patellar tendon or quadriceps tendon has been stretched.

Muscle examinations should consider superimposed factors like relaxed, unstable joints. The degree of actual muscle weakness is difficult to judge in such cases. From the standpoint of function, the muscle is weak and should be so graded. When the muscle exhibits a strong contraction, however, it is important to recognize this as the potential for improvement. In a muscle that fails to function because of joint instability rather than because of weakness of the muscle itself, treatment should be directed at correcting the joint problem and relieving strain on the muscle. For example, it is not uncommon for the deltoid muscle to show a "fullness" of contraction throughout the muscle belly yet fail to lift the weight of the arm. Such a muscle should be protected from strain by application of an adequate support for the express purpose of allowing the joint structures to shorten to their normal position. Failure to distinguish between real and apparent muscle weakness resulting from joint instability may deprive a patient of adequate follow-up treatment.

Test Position. Test position is the position in which the segment is placed by the examiner and held (if possible) by the patient. It is the position used for the purpose of evaluating strength for most muscles because the segment and relevant musculature is aligned such that accurate testing of that muscle's strength be can be assessed.

The **optimal test position** is at the completion of range for one-joint muscles and for two- or multi-joint muscles that act like one-joint muscles. The optimal test position for other two- or multi-joint muscles is at mid-range of overall length, in accordance with the length-tension principle.

Use of the test position also enables the examiner to detect compensatory movements. When muscle weakness exists, other muscles immediately act in an attempt to hold a position resembling the test position. The visible shift from the test position indicates a compensatory movement.

Placing the segment in the test position expedites grading the muscle strength. As the effort is made to hold the test position, the ability or inability to hold the position against gravity is at once established. If it fails to hold, the examiner tests for strength below the fair grade. If the position is held, the examiner then applies pressure to grade above fair (Table 1-3).

TABLE 1-3 Key to Muscle Grading

	Function of Muscle	Muscle Grades and Symbols				
No Movement	No contraction felt or seen in the muscle	Zero	0	0	0	0
	Tendon becomes prominent or feeble contraction felt in muscle with no visible movement	Trace	T	1	T	
Supported in the Horizontal Plane*	Movement through partial range of motion	Poor–	P–	2–	1	+
	Movement through complete range of motion for the muscle being tested	Poor	P	2	2	
	Holds against slight pressure in test position**	Poor+	P+	2+	3	
Tests in the Antigravity Position	Moves through partial range of motion against gravity	Poor+	P+	2+	3	
	Gradual release from test position occurs	Fair–	F–	3–	4	
	Holds test position (no added pressure)	Fair	F	3	5	++
	Holds test position against slight pressure	Fair+	F+	3+	6	
	Holds test position against slight to moderate pressure	Good–	G–	4–	7	
	Holds test position against moderate pressure	Good	G	4	8	+++
	Holds test position against moderate to strong pressure	Good+	G+	4+	9	
	Holds test position against strong pressure	Normal	N	5	10	++++

*Support of the part being tested should ideally be provided by a firm, smooth surface that minimizes resistance to movement in the horizontal plane, such as a powder board.

**Testing for a Poor+ grade in the horizontal plane requires that the muscle being tested (1) be able to move the part through the muscle's range of motion without resistance (Poor grade), then (2) be able to hold against slight pressure in the test position where it exhibits greatest strength (e.g., Class I and II muscles should be tested at completion of range, while Class III and IV muscles should be tested at midrange of overall length of muscle.)

According to the Key, the highest test movement grade in the antigravity position is a 3, or Poor+. Test movements for lateral trunk flexors, upper and lower abdominal muscles, and back extensors are exceptions. See individual tests for grading of these muscles.

Testing of the muscles of the fingers and toes does not depend on gravity. See Chapter 6.

Test Movement. Test movement is a movement of a segment in a specified direction and through a specific arc of motion. For strength tests of extremity muscles that are too weak to act against gravity (i.e., muscles that grade in the range of poor), tests are done in the horizontal plane. Test movement is also used when testing the trunk lateral flexors, upper abdominal flexors, back extensors, quadratus lumborum, serratus anterior (in standing), and gastrocnemius.

Test movement may be used for certain muscles, such as those that cross hinge joints, but it is not practical when a test requires a combination of two or more joint positions or movements. It is difficult for a patient to assume the exact position through verbal instruction or imitating a movement demonstrated by the examiner. For accurate testing, the examiner should place the segment in precisely the desired test position.

Pressure

The term **pressure** is used throughout this text to refer to the external force that is applied by the examiner to determine the strength of the muscle holding in the test *position* (i.e., for grades of F+ or better).

The term **resistance** refers to the external force that opposes the test *movement.* The resistance may be the force of gravity or a force that is supplied by the examiner. Resistance may vary according to body weight (i.e., back extensor test), arm position (i.e., upper abdominal test), or leg positions (i.e., lower abdominal test). Occasionally, the examiner may offer resistance. An example of this is the traction the examiner provides in the quadratus lumborum test.

The placement, direction, and amount of pressure/resistance are important factors when testing for strength above the grade of fair. In the descriptions of muscle tests, pressure is specified as against or in the direction of. *Against* refers to the position of the examiner's hand in relation to the patient; *in the direction of* describes the direction of the force that is applied directly opposite to the line of pull of the muscle or its tendon.

In some of the illustrations of muscle tests, the examiner's hand has been held extended for the purpose of indicating, photographically, that the direction of pressure is perpendicular to the palmar surface of the hand. Pressure should be applied only in the direction indicated. (It is not necessary that the extended hand position be imitated during routine muscle testing.) An extended hand is not appropriate when applying pressure in a test that includes a rotation component.

Just as the direction of the pressure is an important component of accurate test performance, the *amount* of pressure is the determining factor in grading strength above fair (see *Grading*).

The *place* at which the pressure is applied depends on muscle insertions, strength of intervening muscles, and leverage. As a general rule, pressure is applied near the distal end of the segment on which the muscle is inserted. For example, pressure is applied near the distal end of the forearm during the biceps test. Exceptions to this rule occur when pressure on the bone of insertion does not provide adequate leverage to obtain discrimination for grading or when a patient cannot tolerate application of pressure at that site for some reason.

Both the length of the lever and the amount of pressure are closely related with respect to grading above fair. Using a long lever gives the examiner a mechanical advantage and allows more sensitive grading of muscle strength. Test results might be more indicative of the lack of strength of the examiner than of the subject if the examiner did not have the advantage of leverage.

When testing strong muscles like hip abductors, it is necessary to use a long lever (i.e., placing pressure just proximal to the ankle). When testing hip adductors, however, it is necessary to use a shorter lever, with pressure just above the knee joint, to avoid strain on the anteromedial area of that joint.

Pressure must be applied *gradually* to determine the degree of strength above fair in muscles. The patient must be allowed to *get set and hold* the test position against the examiner's pressure. The examiner cannot gauge the degree of strength unless pressure is applied gradually, because slight pressure that is applied suddenly can break the pull of a strong muscle. Grading strength involves a subjective evaluation based on the amount of pressure applied. Differences in strength are so apparent, however, that an observer who understands grading can estimate the strength with a high degree of accuracy while watching the examiner apply pressure.

Compensatory Presentations

Compensation results from one or more muscles attempting to compensate for the lack of strength in another muscle or group of muscles. Compensation is a good indication that the tested muscle is weak, that adequate fixation has not been applied, or that the subject has not been given adequate instruction concerning how to perform the test. Muscles that normally act together in movements may act in compensation. These include fixation muscles, agonists, and antagonists.

Compensation by fixation muscles occurs specifically in relation to movements of the shoulder joint and the hip joint. Muscles that move the scapula may produce a secondary movement of the arm; muscles that move the pelvis may produce a secondary movement of the thigh. These compensatory movements appear similar to—but are not—movements of the shoulder or hip joint.

The close relationship of muscles determines their action in compensation, assistance, and stabilization during tests of individual muscles. The grouping of muscles according to joint action, as seen in the charts in Chapters 6 and 7, has been done to aid the examiner in understanding the allied action of muscles.

True abduction of the hip joint is accomplished by hip abductors with normal fixation by the lateral trunk muscles. When the hip abductors are weak, apparent abduction may occur by the compensatory action of lateral trunk muscles. The pelvis is hiked up laterally, the leg is raised from the table, but no true hip joint abduction occurs.

Antagonists may produce movements similar to test movements. If finger flexors are weak, action of the wrist extensors may produce passive finger flexion by the tension placed on flexor tendons.

Compensation by other **agonists** results in either a movement of the segment in the direction of the stronger agonist or a shift of the body in a way that favors the pull of that agonist. For example, during the gluteus medius test in side-lying, the thigh will tend to flex if the tensor fasciae latae is attempting to compensate for a weak gluteus medius, or the trunk may rotate back so that the tensor fasciae latae can hold a position that appears to be the desired test position.

For accurate muscle examinations, no compensations should be permitted. The position or movement described as the test should be done without shifting the body or turning the segment. Such secondary movements allow other muscles to substitute for the weak or paralyzed muscle.

An experienced examiner who is aware of the ease with which normal muscles perform the tests will readily detect compensations. When test position is employed instead of test movement, even an inexperienced examiner can detect the sudden shift of the body or the segment that results from an effort to compensate for the muscle weakness.

Presentation of Weakness, Shortness, and Contracture

Included with the descriptions of the muscles in this text is a discussion of the loss of movement or the position of deformity that results from muscle weakness or muscle shortness.

Weakness is used as an overall term that covers a range of strength from zero to fair in non-weight-bearing muscles but also includes fair+ in weight-bearing muscles. Weakness will result in loss of movement if the muscle cannot contract sufficiently to move the part through partial or complete range of motion.

A contracture or shortness will result in loss of motion if the muscle cannot be elongated through its full range of motion. **Contracture** refers to a degree of shortness that results in a marked loss of range of motion. **Shortness** refers to a degree of shortness that results in slight to moderate loss of range of motion.

A fixed deformity usually does not exist as a result of weakness unless contractures develop in the stronger opponents. In the wrist, for example, a fixed deformity will not develop as a result of wrist extensor weakness unless the opposing flexors maintain the position of wrist flexion.

A state of **muscle imbalance** exists when a muscle is weak and its antagonist is strong. The stronger of the two opponents tends to shorten, and the weaker of the two tends to elongate. Either weakness or shortness can cause faulty alignment. Weakness permits a position of deformity, but shortness creates a position of deformity.

In some regions of the body, positions of deformity may develop as a result of weakness even though the opposing muscles do not become contracted. A hyperkyphotic position of the upper back may result from weakness of the upper back muscles regardless of whether the anterior trunk muscles become contracted. A position of pronation of the foot may exist if the inverters are weak because the body weight in standing will distort the bony alignment. If opposing fibular (peroneal) muscles become contracted, a fixed deformity will result.

The word **tight** has two meanings. It may be used interchangeably with the term **short**, or it may be used to mean **taut**, in which case it may be applied to either a short or a stretched muscle. On palpation, hamstrings that are short and drawn taut will feel tight. Hamstrings that are stretched and drawn taut will also feel tight. From the standpoint of prescribing treatment, it is very important to recognize the difference between stretched muscles and shortened muscles. In addition, some muscles are short and remain in what appears to be a state of semi-contraction. On palpation, they feel firm or even rigid without being drawn taut. For example, posterior neck and upper trapezius muscles often are tight in people with bad posture of the upper back, head, and shoulders.

RANGE-OF-JOINT MOTION AND MUSCLE LENGTH TESTING

The phrases range of joint motion (range of motion (ROM)) and range of muscle length (extensibility) have specific meanings. **Range of joint motion** refers to the number of degrees of motion that are present in a joint. Descriptions of joints and the joint measurement charts include references to normal ranges of joint motion. **Range of muscle length**, also expressed in terms of degrees of joint motion, refers to the length of the muscle.

For muscles that pass over one joint only, the range of joint motion and range of muscle length will measure the same. Both may be normal, limited, or excessive. In some instances, when measuring range of joint motion, it is necessary to allow the muscle to be slack over one joint to determine the full range of joint motion in the other. For example, when measuring the range of knee joint flexion, the hip is flexed to allow the rectus femoris to be slack over the hip joint and permit full range of joint motion at the knee. When measuring range of hip joint flexion, the knee is flexed to allow the hamstrings to be slack over the knee joint and permit full range of joint motion at the hip.

Measuring Joint Motion and Muscle Length

It is easier and more accurate to use a measuring device that permits the stationary arm of the caliper to rest on the table and the examiner to place the movable arm in line with or parallel to the axis of the humerus or femur, as the case may be. The fulcrum will be shifted to permit this change, but the angle will remain the same—as if the stationary arm were held parallel to the table along the trunk in line with the shoulder joint or hip joint.

Correlation Between Joint Range and Muscle Length

An interesting correlation exists between the total range of joint motion and the range of muscle length chosen as a standard for hamstring and hip flexor length tests. In each case, the muscle length adopted as a standard is approximately 81% of the total range of joint motion of the two joints over which the muscles pass. The following are the joint ranges considered to be normal:

Hip—30° extension, 125° flexion, for a total of 155°
Knee—0° (10°) extension, 135° flexion, for a total of 135° (145)°
Total of both joints—290°

Hip flexor length test used as a standard: Supine, with the low back and sacrum flat on the table, hip joint extended, and hip flexors elongated 155° over the hip joint. With the knee flexed over the end of the table at an angle of 80°, the two-joint hip flexors are elongated 80° over the knee joint, for a total of 215°. Thus, 215° divided by 290° is 78.18%, and range of muscle length is 81% of total joint range.

Hamstring length test used as a standard: Supine, with the low back and sacrum flat on the table and straight-leg raising to an 80° angle with table. Hamstrings are elongated 155° over the knee by full extension and 80° over the hip joint by the straight-leg raising, for a total of 235°. Thus, 235° divided by 290° equals 81%, and range of muscle length is 81% of total joint range.

Muscle Length Tests

Muscle length tests are performed to determine whether the range of muscle length is normal, limited, or excessive. Muscles that are excessive in length are usually weak and can allow adaptive shortening of opposing muscles; muscles that are too short are usually strong and maintain opposing muscles in a lengthened position.

Muscle length testing consists of movements that increase the distance between origin and insertion, thereby elongating muscles in directions opposite to those of the muscle actions.

Accurate muscle length testing usually requires that the bone of origin be in a fixed position while the bone of insertion moves in the direction of lengthening the muscle. Length tests use passive or active-assisted movements to determine the extent to which a muscle can be elongated.

Grading Muscle Strength

Grades represent an examiner's assessment of the strength or weakness of a muscle or a muscle group. In manual muscle testing, grading is based on a system in which the ability to hold the tested segment in a given position against gravity establishes a grade referred to as fair or the numerical equivalent (depending on the grading symbols being used). The grade of fair is the most objective grade because the pull of gravity is a constant factor.

For grades above fair, pressure is applied in addition to the resistance offered by gravity. A **break test** is a muscle strength test to determine the maximal effort exerted by a subject who is performing an isometric contraction as the examiner applies a gradual buildup of pressure to the point that the effort by the subject is overcome. It is used in determining grades of fair+ through good+.

No effort is made to break the subject's hold if the examiner has determined that the strength is normal. To continue exerting force to make the muscle yield by performing a break test is unnecessary and may even be injurious.

The symbols used in grading vary and include the use of words, letters, numbers, or other signs. To avoid listing the equivalents each time this text refers to a grade, the symbols are used in the descriptions of grades below.

Gravity is a form of resistance that is basic to manual muscle testing. It is used in tests of the trunk, neck, and extremity muscles. It is a factor, however, only in approximately 60% of the extremity muscles. It is not required in tests of finger and toe muscles because the mass of the segment is so small in comparison with the strength of the muscle that the effect of gravity on the segment is negligible. Another example is supination and pronation of the forearm. These are movements of rotation in which the effect of gravity is also not a significant factor.

Testing muscles that are very weak involves movements in the horizontal plane on a supporting surface where the resistance by gravity is decreased. To avoid use of phrases such as gravity-lessened, gravity-decreased, or gravity-minimized, the text and the *Key to Muscle Grading* will refer to movements in the horizontal plane.

Detailed grading of muscle strength is more important in relation to prognosis than to diagnosis. The extent of involvement may be determined by such simple grading as zero, weak, and normal. On the other hand, more precise grading helps to establish the rate and degree of return of muscle strength and is also useful in determining a prognosis. A muscle might appear to be weak for months, although the record shows that it has progressed from poor to fair during this same period.

Accuracy in grading depends on many factors: the stable position of the patient, the fixation of the segment proximal to the segment being tested, the precision of the test position, and the direction and amount of pressure. The amount of pressure varies with the age and the size of the patient, the segment being tested, and the leverage. If one extremity is unaffected, the examiner may use the strength in the unaffected extremity as an index for the patient's normal strength when testing the affected extremity.

An examiner must build a basis for comparison of test results through experience in muscle testing. Such experience is necessary when testing both paralytic and normal individuals. For many, however, experience in muscle testing is insufficient or has been limited to the examination of patients with disease or injury. As a result, these examiners' idea of normal strength tends to be a measure of what appears to be good functional recovery following weakness or injury.

To gain experience, according to the Kendalls, an examiner must make an effort to test individuals of all ages and body types as well as those with good and faulty postures. If it is not possible to examine a large number of normal individuals, an effort should be made to examine the trunk and unaffected extremities in cases involving only one or two extremities.

Testing and grading procedures are modified during examination of infants and children to the age of 5 or 6 years. The ability to determine a child's muscle strength up to the grade of fair is usually not difficult, but grading strength above fair depends on the understanding and cooperation of the child in holding against resistance or pressure. Young children seldom cooperate in strong test movements. Very often, tests must be recorded as "apparently normal," which indicates that although the strength may, in fact, be normal, one cannot be sure.

Grading Symbols

Robert W. Lovett, M.D., introduced a method of testing and grading muscle strength using gravity as resistance (21). A description of the Lovett system was published in 1932 and listed the following definitions:

Gone—no contraction felt.
Trace—muscle can be felt to tighten but cannot produce movement.
Poor—produces movement with gravity eliminated but cannot function against gravity.
Fair—can raise the segment against gravity.
Good—can raise the segment against outside resistance as well as against gravity.
Normal—can overcome a greater amount of resistance than a good muscle.

The symbols used may vary, but the movement and weight factors set forth by Lovett form the basis of most current muscle testing. The Kendalls introduced the use of numbers for computing the amount of change in muscle strength when doing research with patients recovering from poliomyelitis. They had used the word and letter symbols previously and, for the most part, it was possible to translate grades from one scale to the other.

The Kendalls believed it was in the best interest of those who engage in manual muscle testing that an effort be made to standardize (as much as possible) the descriptions of the tests and the symbols used. Numerals are commonly used and such use is needed for research that involves muscle test grades.

Table 1-3 is basically the same as the Lovett system, but with added definitions for the minus and plus grades. The poor+ grade provides for movement in the horizontal plane and for partial arc against gravity.

In this text, the normal minus (N–) grade has been eliminated, and the scale has been changed from 0 to 10. Leaving zero as 0 and trace as T, the word and letter symbols translate directly as indicated in Table 1-3. No movement is involved with the 0 and T grades, and the numerals 1–10 refer to test movement and test position grades.

Grades above Fair

Standardization of muscle testing techniques related to grading strength above fair requires a specific place in the arc of motion where the segment is held by the subject as manual pressure is applied.

Muscle strength is not constant throughout the range of motion, and in manual muscle testing, it is not practical to try to grade the strength at various points in the arc of motion (see *Grading* for the place in the arc used as the position for grading).

If the test position is used, the segment is placed in the specific position by the examiner and then pressure is applied. For there to be standardization of testing techniques and grading when test movement is used, the movement must proceed to the same place in the arc of motion as that established as the test position. For this reason, the movement factor is omitted in Table 1-3 when defining grades above fair.

Normal Grade

The grade of **normal** means that the muscle can hold the test position against gravity and strong pressure. This grade is not intended to indicate the maximum strength of the subject, but rather the maximum pressure that the examiner applies to determine what might be termed as full strength of the muscle. In terms of judgment, it might be described as strength that is adequate for ordinary functional activities. To become competent in judging this full strength, an examiner should test normal individuals of various ages, sizes, and genders.

It should be noted that the term *normal* has a variety of meanings. It may mean average, typical, natural, or standard. If one adheres to the definition used when muscle grading, a grade of poor will be recorded for a small child who cannot lift the head in flexion from a supine position. Knowing that it is natural for small children to exhibit weakness of the anterior neck muscles, an examiner might say this child's neck is normal, using normal in the sense that it is natural. On administering a leg-lowering test for abdominal strength in a large group of adolescent children and finding that a grade of fair+ or good– is the average strength for the group, one might say that this grade of strength is normal for this age. Thus, we have three different uses of *normal* applied rather freely in muscle testing: standard, natural, and average.

Because normal is defined as a standard when used in the scale of grading, grades of strength should relate to that standard, and appropriate terms other than normal should be used in the interpretation of results. One of the advantages of using numerical grades is that it leaves the term *normal* free for use in the interpretation of those grades. In the following discussion, this term will be employed in this manner.

Most grades are based on adult standards, so it is necessary to acknowledge what is normal for children of a given age. This is particularly true regarding the strength of the anterior neck and anterior abdominal muscles. The size of the head and trunk in relation to the lower extremities as well as the long span and normal protrusion of the abdominal wall affect the relative strength of these muscles. Anterior neck muscles may grade about poor+ in a 3-year-old child, about fair in a 5-year-old child, and gradually increase up to the standard of performance for adults by 10 or 12 years of age. Many adults will exhibit no more than fair+ strength. This need not be interpreted as neurogenic, however, because it usually is associated with faulty posture of the head and upper back.

The prime example of a standard that is an infant rather than an adult accomplishment is that of toe flexor strength. In general, children have more strength in their toe flexors than many adults do. It is not uncommon to find that women who have worn high heels and rather narrow-toed shoes have weakness of toe flexors in which the grade is no more than fair–. With the standard being the ability to flex the toes and hold against strong resistance or pressure, the adult must be graded against that standard; however, this weakness of the toe flexors should not be interpreted as being normal for age. One becomes so accustomed to toe flexor weakness among adults that a degree of weakness might be assumed to be normal in the sense that "normal" is "average." Marked weakness of the toe flexors is almost invariably associated with some degree of disability of the foot. However, the term *normal* should not apply to such weakness unless one is ready to accept the disability itself as being normal.

This toe flexor weakness represents a loss of strength from childhood to adulthood, and it should be regarded as an unnatural, acquired weakness. This type of weakness may be present in other muscles as a result of stretch and strain associated with occupational or recreational activities or faulty posture. Acquired weakness usually does not drop below the grade of fair, but fair and fair+ grades of strength might be interpreted as neurogenic if one were not aware that such degrees of weakness can result from stretch and strain of the muscles.

Good Grade

The grade of **good** means that the muscle can hold the test position against moderate pressure.

Fair Grade

The grade of **fair** indicates that a muscle can hold the segment in test position against the resistance of gravity but cannot hold if even slight pressure is added. In tests such as those for the triceps and quadriceps, the examiner should avoid a locked (closed-packed) position of the joint that could give undue advantage to a muscle that was slightly less than fair in strength.

When considering a fair grade, the question arises of whether the strength to hold the test position is equivalent to the strength required to move through range of motion to the test position. With some exceptions, the general rule is that the test movement can be performed if the test position can be held.

In some muscle tests, the bone on which the muscle is inserted moves from a position of suspension in the vertical plane toward the horizontal plane. The quadriceps, deltoid, and hip rotators tested in the sitting position and the triceps and shoulder rotators tested in the prone position compose this group. The leverage exerted by the weight of the segment increases as the segment moves toward completion of the arc, and the muscle strength required to hold the test position against gravity usually is sufficient to perform the test movement against gravity.

In a few tests, the bone on which the muscle is inserted moves from a horizontal position toward a vertical position, and less strength is required to hold the test position than is needed to perform the test movement. This occurs during tests of hamstrings when tested by knee flexion in the prone position and tests of the elbow flexors when examined in the supine position.

Poor Grade

The ability to move through a partial arc of motion in the horizontal plane is graded as **poor–**. The grade of **poor** means that the muscle is capable of completing the range of motion in the horizontal plane. The grade of **poor+** denotes the ability to move in the horizontal plane to completion of the range of motion against resistance or to hold the completed position against pressure. It also means that the muscle is capable of moving through a partial arc of motion in the antigravity position.

The ranges of strength within the grade of poor are significant enough to deserve these subclassifications for purposes of more definitive grading. The ability to perform the full range of motion in the horizontal plane is not close to the ability to perform the test against gravity for most muscles. Adding pressure or resistance to the element of movement in the horizontal plane provides the added force that approaches that of gravity in the antigravity position.

Testing for the various grades of poor is justified and meaningful when used appropriately. In the rehabilitation of persons with severe neuromuscular and musculoskeletal involvement, the minute but visible changes that show improvement are very important. Maintaining a record of these significant changes, however slight, is important to the morale and continuing motivation of the patient and is necessary in determining his or her progress and the justification for continued care. These small changes can be as meaningful to a patient as the gains achieved by a recovering athlete at the later stages of rehabilitation.

The overall grade of poor can be assigned without unnecessary changes of position required for testing in the horizontal plane. If it has been determined that the muscle does not grade a fair minus (F–) by the test in the antigravity position but does grade more than a trace (which can be established in almost any position), then the overall grade of poor can be assigned without any need for further testing.

In practice, clinicians must realize frequent changes of position or repetition of a test in various positions may be tiring for a patient and time-consuming for the examiner. Patients should not be subjected to unnecessary procedures during examination if the results obtained are not meaningful.

Tests in the horizontal plane include several variables. The partial range of motion for the poor– grade is not specific, because there is no indication of where in the arc of motion the partial range should be. It may be at the beginning of the range of motion, within the midrange, or near the end.

With respect to partial arc of motion in antigravity position for a poor+ grade, it may mean starting from the suspended (i.e., vertical) position for quadriceps. For the hamstrings, it may mean that in the prone position, the subject can flex the last few degrees required to bring the leg to the vertical position.

When testing hip extensors or hip flexors in the side-lying position, a horizontal movement through the range of motion furnishes a means to obtain an objective grade of poor. The surface of the table, smooth or rough, changes the amount of friction and resistance. The strength of the hip adductors (if the underneath leg is being tested) may make a material difference in the results of the flexor and extensor tests. If the adductors are paralyzed, the full weight of the extremity will rest on the table and make flexion and extension difficult. If the adductors are strong, they will tend to raise the extremity so that the full weight does not rest on the table, thereby reducing the friction, and the flexion and extension movements will thus be made easier.

Trace Grade

The grade of **trace** means that a contraction can be appreciated by palpation and/or observation in a muscle or tendon as it becomes slightly prominent; however, no movement of the segment is visible. Trace grades can be determined in almost any position.

When testing very weak muscles, the examiner usually moves the segment into test position and tries to help the patient feel the movement and elicit a muscle response. The examiner should be sure that the movement starts from a relaxed position. If the segment is carried to the beginning of the range of motion and slight tension is put on the muscle, there may be a rebound or springing back, which can be confused with active movement.

Zero Grade

The grade of **zero** is assigned when no evidence of any muscle contraction is visible or palpable.

Key to Muscle Grading

According to Table 1-3, the highest test movement grade in the antigravity position is a 3, or poor+. Test movements for lateral trunk flexors, upper and lower abdominal muscles, and back extensors are exceptions. See individual tests for grading of these muscles. Testing of the muscles of the fingers and toes does not depend on gravity.

SECTION III
NERVE AND MUSCLE CHARTS

MUSCLE INNERVATIONS, SPINAL NERVES, AND MUSCLE CHARTS

The recording of test results is an important component of muscle examinations. Records are valuable from the standpoints of diagnosis, treatment, prognosis, and progress. An examination performed without recording the details can be of value at the moment, but one has an obligation to the patient, to the institution (if one is involved), and to oneself to record the findings.

Charts used for recording the findings of muscle examinations should permit complete tabulation of test results. In addition, the arrangement of the information should facilitate its interpretation. There are two charts in this category provided by Florence Kendall: one for the neck, diaphragm, and upper extremity and the other for the trunk and lower extremity. These charts have been designed especially for use as an aid in the differential diagnosis of lesions of the spinal nerves (Box 1-2). The motor involvement, as determined by manual muscle tests, can aid in determining whether a lesion of the nerve exists at the root, plexus, or peripheral level. The charts may also be useful in determining the level of a spinal cord lesion.

Use of the *Spinal Nerve and Muscle Charts* is illustrated by the case studies in Chapters 6 and 7.

In the upper and lower extremity charts, the names of the muscles appear in the left column and are grouped, as indicated by heavy black lines, according to their innervations, which are listed to the left of the muscle names. The space between the column of muscle names and the nerves is used to record the grade of muscle strength. Following is a brief description of a few sections of these extremity charts.

Peripheral Nerves

Peripheral nerves and their segmental origins are listed across the top of the center of the chart and follow the order of proximal-distal branching insofar as possible. For the peripheral nerves that arise from cords of the brachial plexus, the appropriate cord is indicated. The key at the top of the charts explains the abbreviations used.

Below this section, in the body of the chart, the dots indicate the peripheral nerve supply to each muscle (see Appendix D for sources of material for this section.)

BOX 1-2

Use of Charts in Differential Diagnosis

- Muscle strength grades are recorded in the column to the left of the muscle names. The grade symbols may be numerals or letters. Grades can be translated as indicated on the *Key to Grading Symbols*.
- After the grades have been recorded, the nerve involvement is plotted, when applicable, by circling the dots under peripheral supply or outlining the numbers under spinal segment distribution that corresponds with each involved muscle (see Chapters 6 and 7).
- The involvement of peripheral nerves and/or parts of the plexus is ascertained from the encircled dots by following the vertical lines upward to the top of the chart or the horizontal to the left margin. When evidence of involvement at spinal segment level exists, the level of the lesion may be indicated by a heavy black line drawn vertically to separate the involved from the uninvolved spinal segments.
- As a rule, muscles graded as good (i.e., 8) or above may be considered as not being involved from a neurological standpoint. This degree of weakness may be the result of factors such as inactivity, stretch weakness, or lack of fixation by other muscles. It should be remembered, however, that a grade of good might indicate a deficit of a spinal segment that minimally innervates the muscle.
- Weakness with grades of fair or less may be the result of inactivity, disuse atrophy, immobilization, or neurological problems. Faulty posture of the upper back and shoulders may cause weakness of the middle and lower trapezius. It is not uncommon to find bilateral weakness of these muscles with grades as low as fair–. A neurological problem with involvement of the spinal accessory nerve is unlikely in cases of isolated weakness of these muscles, unless there is also involvement of the upper trapezius.

Spinal Segment

In this section, a number denotes the spinal segment origin of nerve fibers innervating each of the muscles listed in the left column (see Appendix D for sources for material for this section).

In the accompanying spinal nerve and muscle charts and subsequent text, distribution is indicated by numbers. Major distribution is indicated by a number in bold type, a small distribution by a number in regular type, and a possible or infrequent distribution by a number in parenthesis.

Sensory

On the right side of the charts are diagrams showing the dermatomes and the distribution of cutaneous nerves for the upper extremity on one and for the trunk and lower extremity on the other (17, 22).

It is possible to use the illustrations for charting areas of sensory involvement by shading or using a colored pencil to outline the areas of the involvement for any given patient. Only drawings of the right extremity are used on the extremity charts, but labeling can indicate, when necessary, that the recorded information pertains to the left side.

Neck, Diaphragm, and Upper Extremity

See Figure 1-10 for grading muscle strength of the neck, diaphragm, and upper extremity.

Trunk and Lower Extremity

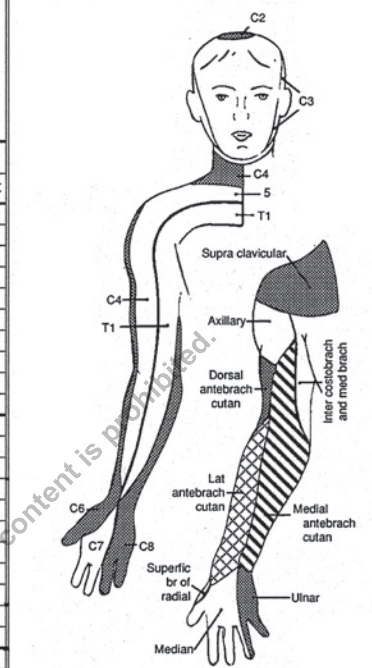
See Figure 1-11 for grading muscle strength of the trunk and lower extremity.

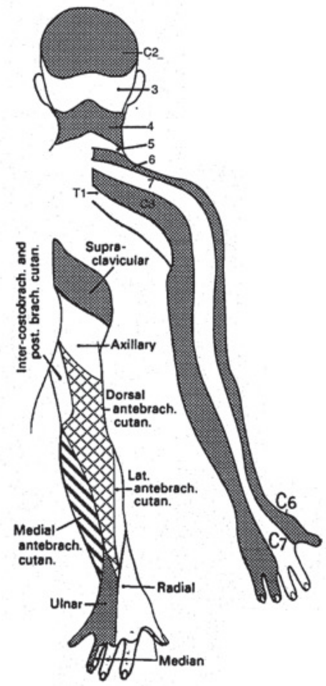
Name Date

		MUSCLE STRENGTH GRADE	MUSCLE	Cervical D. 1-8, T. 1	Cervical V. 1-8	Cervical V. 1-4	Phrenic V. 3, 4, 5	Long Thor. P.R. 5, 6, 7, (8)	Dor. Scap P.R. 4, 5	N. to Subcl. S.T. 5, 6	Suprascap S.T. 4, 5, 6	U. Subscap. P. (4), 5, 6, (7)	Thoracodor P. (5), 6, 7, 8	L. Subscap. P. 5, 6, (7)	Lat. Pect. L. 5, 6, 7	Med. Pect. M. (6), 7, 8, T. 1	Axillary P. 5, 6	Musculocu. L. (4), 5, 6, 7	Radial P. 5, 6, 7, 8, T. 1	Median L.M. 5, 6, 7, 8, T. 1	Ulnar M. 7, 8, T. 1	C1	C2	C3	C4	C5	C6	C7	C8	T1
			HEAD & NECK EXTENSORS	•																		1	2	3	4	5	6	7	8	1
Cervical Nerves			INFRAHYOID MUSCLES			•																1	2	3						
			RECTUS CAP ANT. & LAT.			•																1	2							
			LONGUS CAPITIS			•																1	2	3	(4)					
			LONGUS COLLI		•																		2	3	4	5	6	(7)		
			LEVATOR SCAPULAE			•			•															3	4	5				
			SCALENI (A. M. P.)		•																			3	4	5	6	7	8	
			STERNOCLEIDOMASTOID			•																(1)	2	3						
			TRAPEZIUS (U. M. L.)			•																	2	3	4					
			DIAPHRAGM				•																	3	4	5				
Brachial Plexus	Root		SERRATUS ANTERIOR					•																		5	6	7	8	
			RHOMBOIDS MAJ & MIN						•																4	5				
	Trunk		SUBCLAVIUS							•																5	6			
			SUPRASPINATUS								•														4	5	6			
			INFRASPINATUS								•														(4)	5	6			
	P Cord		SUBSCAPULARIS									•		•												5	6	7		
			LATISSIMUS DORSI										•														6	7	8	
			TERES MAJOR											•												5	6	7		
	L		PECTORALIS MAJ (UPPER)												•											5	6	7		
	M&L		PECTORALIS MAJ (LOWER)												•	•											6	7	8	1
			PECTORALIS MINOR													•											(6)	7	8	1
Axil.			TERES MINOR														•									5	6			
			DELTOID														•									5	6			
Musculo-	cutan		CORACOBRACHIALIS															•									6	7		
			BICEPS															•								5	6			
			BRACHIALIS															•								5	6			
Radial			TRICEPS																•								6	7	8	1
			ANCONEUS																•									7	8	
	Lat.M		BRACHIALIS (SMALL PART)																•							5	6			
			BRACHIORADIALIS																•							5	6			
			EXT CARPI RAD L																•							5	6	7	8	
	Post Inter		EXT CARPI RAD B																•							5	6	7	8	
			SUPINATOR																•							5	6	(7)		
			EXT DIGITORUM																•								6	7	8	
			EXT DIGITI MINIMI																•								6	7	8	
			EXT CARPI ULNARIS																•								6	7	8	
			ABD POLLICIS LONGUS																•								6	7	8	
			EXT POLLICIS BREVIS																•								6	7	8	
			EXT POLLICIS LONGUS																•								6	7	8	
			EXT INDICIS																•								6	7	8	
Median			PRONATOR TERES																	•							6	7		
			FLEX CARPI RADIALIS																	•							6	7	8	
			PALMARIS LONGUS																	•							(6)	7	8	1
			FLEX DIGIT SUPERFICIALIS																	•								7	8	1
	A Inter		FLEX DIGIT PROF I & II																	•								7	8	1
			FLEX POLLICIS LONGUS																	•							(6)	7	8	1
			PRONATOR QUADRATUS																	•								7	8	1
			ABD POLLICIS BREVIS																	•							6	7	8	1
			OPPONENS POLLICIS																	•							6	7	8	1
			FLEX POLL BREV (SUP. H)																	•							6	7	8	1
			LUMBRICALES I & II																	•							(6)	7	8	1
Ulnar			FLEX CARPI ULNARIS																		•							7	8	1
			FLEX DIGIT. PROF. III & IV																		•							7	8	1
			PALMARIS BREVIS																		•							(7)	8	1
			ABD DIGITI MINIMI																		•							(7)	8	1
			OPPONENS DIGITI MINIMI																		•							(7)	8	1
			FLEX DIGITI MINIMI																		•							(7)	8	1
			PALMAR INTEROSSEI																		•								8	1
			DORSAL INTEROSSEI																		•								8	1
			LUMBRICALES III & IV																		•							(7)	8	1
			ADDUCTOR POLLICIS																		•								8	1
			FLEX POLL BREV. (DEEP H.)																		•								8	1

KEY → D. = Dorsal Prim. Ramus; V. = Vent. Prim. Ramus; P.R. = Plexus Root; S.T. = Superior Trunk; P. = Posterior Cord; L. = Lateral Cord; M. = Medial Cord

SENSORY





Dermatomes redrawn from Keegan and Garrett Anat Rec 102. 409. 437. 1948
Cutaneous Distribution of peripheral nerves redrawn from *Gray's Anatomy of the Human Body*. 28th ed

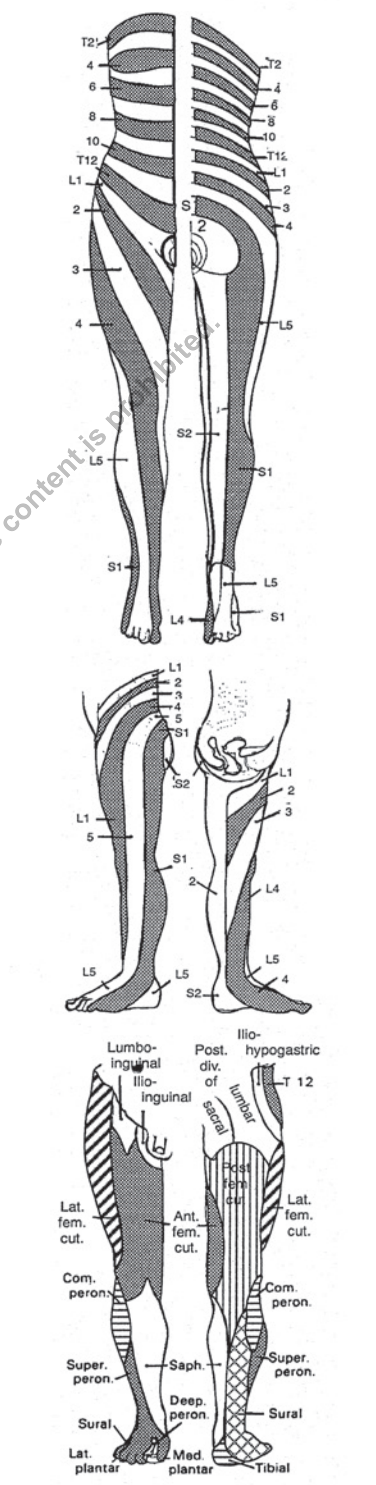
FIGURE 1-10: Grading muscle strength: neck, diaphragm, and upper extremity. © 1993 Florence P. Kendall.

Name Date

KEY
→
D Dorsal Primary Ramus
V Ventral Primary Ramus
A Anterior Division
P Posterior Division

				PERIPHERAL NERVES																	SPINAL SEGMENT							
		MUSCLE STRENGTH GRADE	MUSCLE	D. T1-12, L1-5, S1-3	V. T1, 2, 3, 4	V. T5, 6	V. T7, 8	V. T9, 10, 11, 12	V. Iliohypogastric T12 L1	V. Ilioinguinal T(12) L1	V. Lumb. Plex. T(12) L1, 2, 3, 4	P. Femoral L(1) 2, 3, 4	A. Obturator L(1) 2, 3, 4	P. Sup. Glut. L4, 5, S1	P. Inf. Glut. L5, S1, 2	V. Sac. Plex. L4, 5, S1, 2, 3	P. Sciatic L4, 5, S1, 2	A. Sciatic L4, 5, S1, 2, 3	P. C. Peroneal L4, 5, S1, 2	A. Tibial L4, 5, S1, 2, 3	L1	L2	L3	L4	L5	S1	S2	S3
			ERECTOR SPINAE	•																	1	2	3	4	5	1	2	3
Thoracic Nerves			SERRATUS POST SUP		•																							
Thoracic Nerves			TRANS THORACIS		•	•	•																					
Thoracic Nerves			INT INTERCOSTALS		•	•	•	•																				
Thoracic Nerves			EXT INTERCOSTALS		•	•	•	•																				
Thoracic Nerves			SUBCOSTALES		•	•	•	•																				
Thoracic Nerves			LEVATOR COSTARUM		•	•	•	•																				
Thoracic Nerves			OBLIQUUS EXT ABD			(•)	•	•																				
Thoracic Nerves			RECTUS ABDOMINIS			•	•	•																				
Thoracic Nerves			OBLIQUUS INT ABD				•	•	•	(•)											1							
Thoracic Nerves			TRANSVERSUS ABD				•	•	•	(•)											1							
Thoracic Nerves			SERRATUS POST INF					•																				
Lumb. Plexus			QUAD LUMBORUM								•										1	2	3					
Lumb. Plexus			PSOAS MINOR								•										1	2						
Lumb. Plexus			PSOAS MAJOR								•										1	2	3	4				
Femoral			ILIACUS									•									(1)	2	3	4				
Femoral			PECTINEUS									•	(•)									2	3	4				
Femoral			SARTORIUS									•										2	3	(4)				
Femoral			QUADRICEPS									•										2	3	4				
Obturator	Ant.		ADDUCTOR BREVIS										•									2	3	4				
Obturator	Ant.		ADDUCTOR LONGUS										•									2	3	4				
Obturator	Ant.		GRACILIS										•									2	3	4				
Obturator	Post		OBTURATOR EXT										•										3	4				
Obturator	Post		ADDUCTOR MAGNUS										•					•				2	3	4	5	1		
Gluteal	Sup		GLUTEUS MEDIUS											•										4	5	1		
Gluteal	Sup		GLUTEUS MINIMUS											•										4	5	1		
Gluteal	Sup		TENSOR FAS LAT											•										4	5	1		
Gluteal	In.		GLUTEUS MAXIMUS												•										5	1	2	
Sacral Plexus			PIRIFORMIS													•									(5)	1	2	
Sacral Plexus			GEMELLUS SUP													•									5	1	2	
Sacral Plexus			OBTURATOR INT													•									5	1	2	
Sacral Plexus			GEMELLUS INF													•								4	5	1	(2)	
Sacral Plexus			QUADRATUS FEM													•								4	5	1	(2)	
Sciatic	P.		BICEPS (SHORT H)														•								5	1	2	
Sciatic	Tibial		BICEPS (LONG H)															•							5	1	2	3
Sciatic	Tibial		SEMITENDINOSUS															•						4	5	1	2	
Sciatic	Tibial		SEMIMEMBRANOSUS															•						4	5	1	2	
Common Peroneal	Deep		TIBIALIS ANTERIOR																•					4	5	1		
Common Peroneal	Deep		EXT HALL LONG																•					4	5	1		
Common Peroneal	Deep		EXT DIGIT LONG																•					4	5	1		
Common Peroneal	Deep		PERONEUS TERTIUS																•					4	5	1		
Common Peroneal	Deep		EXT DIGIT BREVIS																•					4	5	1		
Common Peroneal	Sup		PERONEUS LONGUS																•					4	5	1		
Common Peroneal	Sup		PERONEUS BREVIS																•					4	5	1		
Tibial	Tibial		PLANTARIS																	•				4	5	1	(2)	
Tibial	Tibial		GASTROCNEMIUS																	•						1	2	
Tibial	Tibial		POPLITEUS																	•				4	5	1		
Tibial	Tibial		SOLEUS																	•					5	1	2	
Tibial	Tibial		TIBIALIS POSTERIOR																	•				(4)	5	1		
Tibial	Tibial		FLEX DIGIT LONG																	•					5	1	(2)	
Tibial	Tibial		FLEX HALL LONG																	•					5	1	2	
Tibial	Med Pl		FLEX DIGIT BREVIS																	•				4	5	1		
Tibial	Med Pl		ABDUCTOR HALL																	•				4	5	1		
Tibial	Med Pl		FLEX HALL BREVIS																	•				4	5	1		
Tibial	Med Pl		LUMBRICALIS I																	•				4	5	1		
Tibial	Lat Plant		ABD DIGITI MIN																	•						1	2	
Tibial	Lat Plant		QUAD PLANTAE																	•						1	2	
Tibial	Lat Plant		FLEX DIGITI MIN																	•						1	2	
Tibial	Lat Plant		OPP. DIGITI MIN																	•						1	2	
Tibial	Lat Plant		ADDUCTORS HALL																	•						1	2	
Tibial	Lat Plant		PLANT INTEROSSEI																	•						1	2	
Tibial	Lat Plant		DORSAL INTEROSSEI																	•						1	2	
Tibial	Lat Plant		LUMB II,III,IV																	•				(4)	(5)	1	2	

SENSORY



Dermatomes redrawn from
Keegan and Garrett Anat Rec 102. 409. 437. 1948
Cutaneous Distribution of peripheral nerves
redrawn from *Gray's Anatomy of the Human Body*. 28th ed

FIGURE 1-11: Grading muscle strength: trunk and lower extremity. © 1993 Florence P. Kendall.

SECTION IV

CLINICAL FINDINGS

SYSTEM PATHOLOGIES

Numerous neurological and musculoskeletal conditions arise from **noninvasive** trauma that can cause compression or tension (i.e., traction) on a nerve or tissues containing nerve endings. The trauma may be sudden or gradual, with the latter type resulting from intrinsic mechanical barriers, maintained positions, or repetitive movements. Involvement may vary from being widespread throughout an extremity to being localized to a single nerve branch. Noninvasive trauma may be transitory or result in permanent deficits.

Body tissues are subject to **invasive** trauma in many areas of the body, as well. Invasive trauma may be accidental, such as lacerations, piercing wounds, injections of medications, or nerves cut or injured during surgery. Invasive trauma may also be caused by necessary procedures, such as a nerve resection or rhizotomy.

Mechanical Causes of Pain

Pain—whether it is perceived in the muscle, the joint, or the nerve itself—is a response of the nerve. Regardless of where the stimulus may arise, it is conducted by the nerves and interpreted by the brain. The mechanical factors that give rise to pain must, therefore, directly affect the nerve fibers. Two such factors need to be considered in problems of faulty body mechanics: pressure and tension.

Pressure or **compression** on nerve root, trunk, nerve branches, or nerve endings may be caused by some adjacent, firm structure, such as bone, cartilage, fascia, scar tissue, or taut muscle. Pain resulting from ligamentum flavum hypertrophy or a protruded disk exemplifies nerve root pressure. Scalenus anticus syndrome, in cases of arm pain, and piriformis syndrome, in cases of sciatica, are examples of peripheral nerve irritation.

Tension on structures containing nerve endings that are sensitive to deformation, as found in stretch or strain of muscles, tendons, or ligaments, can cause slight or excruciating pain, depending on the severity of the strain. Forces within the body that exert an injurious tension resulting in strain of soft tissue usually arise from a prolonged distortion of bony alignment or from a sudden muscle pull.

Distribution of pain along the course of the involved nerve and the areas of cutaneous sensory disturbance aid in determining the site of the lesion. Pain may be localized below the level of direct involvement or be widespread because of reflex or referred pain. In a root lesion, pain tends to extend from the origin of the nerve to its periphery, and cutaneous sensory involvement is on a dermatomal basis.

Peripheral nerve involvement is often distinguished by pain below the level of the lesion. Most peripheral nerves contain both sensory and motor fibers. Symptoms of pain or tingling usually appear in the cutaneous areas that are supplied by the nerve before numbness or weakness becomes apparent. Numerous muscles are supplied by nerves that are purely motor to the muscle, however, and symptoms of weakness can appear without previous or concurrent symptoms of pain or tingling.

Nerve Compression and Tension

Trauma may also result from an **external force causing compression** on a nerve. *External force causing compression is exemplified by:*

- Radial, median, or ulnar nerve (or some combination of these), as in "Saturday night palsy" from an arm hanging over the back of bench or a chair.
- Radial or median nerve (or both) from crutch paralysis.
- Radial, median, and ulnar nerves from a tourniquet.
- Median nerve from various sleeping positions (e.g., supine, with arm overhead; side-lying on the arm in adduction) (23).
- Ulnar nerve from trauma to the elbow.
- Ulnar or median nerve from sudden or repeated trauma to the hypothenar or thenar eminence.
- Anterior interosseous nerve from (forearm) armband sling (24).
- Brachial plexus from a strap over the shoulder.
- Fibular (peroneal) nerve by a cast, adhesive strapping, or garter producing pressure over the head of the fibula or by prolonged sitting with the legs crossed and one knee resting on the other.
- A transitory external compressive force is exemplified by a bump on the elbow (commonly referred to as hitting the "funny bone," which is so named because it is the distal end of the humerus), which compresses the ulnar nerve. The bruise hurts and causes tingling into the fourth and fifth digits, but the symptoms do not persist.
- Trauma by an external force causing *tension* on nerves can occur to the brachial plexus, such as from an accident or a manipulation that puts excessive traction on the plexus. The long thoracic nerve is susceptible to stretch from carrying a heavy bag with a strap over the shoulder.

- Internal forces created in areas of the body where there is a close association between nerves and firm skeletal structures may result in neural compression or tension. Under ordinary conditions, a groove or a tunnel may protect nerves along their path, but in cases of injury or inflammation with swelling or scar tissue, the confined area becomes a source of entrapment.

Internal compression is exemplified by pressure on:

- Spinal nerve root from calcium deposits in the foramen.
- Suprascapular nerve as it passes under the ligament and through the scapular notch (25–28).
- Brachial plexus from a cervical rib (see posture in relation to cervical rib).
- Brachial plexus from the coracoid process and a tight pectoralis minor (23, 29).
- Axillary nerve in the quadrilateral space (27, 30).
- Median nerve, as in carpal tunnel syndrome.
- Nerve to (usually) the fourth toe, as in Morton's neuroma.

Internal tension on a nerve is exemplified by:

- Suprascapular nerve as it passes through the scapular notch, being subject to stretch with displacement of shoulder and scapula (31).
- Fibular (peroneal) nerve, secondary to spasm in the tensor fasciae latae, with resultant traction on the iliotibial band to its insertion.
- Fibular (peroneal) nerve, secondary to traction on the leg, by inversion of the foot (23, 28).

Nerve Impingement

In this text, the term **impingement** is used with reference to nerve irritation associated with muscles.

During the 1930s, there was great reluctance to speak about the possibility that in addition to bone and other firm structures, muscles might play a role in causing irritation to the nerves. In a 1934 article regarding the piriformis muscle, Albert H. Freiberg stated that "pressure of a muscle belly upon the trunk of the sciatic nerve can be productive of pain and tenderness [but] must be looked upon as unproved at present" (32). Freiberg was cautious and almost apologetic about suggesting that the muscle could play that kind of a role.

During that same era, one of the original authors of *Muscles: Testing and Function*, Henry O. Kendall, rather courageously offered such explanations for several clinical entities. Most instances were related to muscles that were pierced by a peripheral nerve and in which movement and alteration of muscle length were factors in causing a friction type of irritation to the nerve. Symptoms of pain or discomfort could be elicited by stretching the muscle, by having the muscle actively contract, or by repetitive movements.

Explaining peripheral nerve pain on the basis of pressure or friction by muscles remains a controversial issue with respect to certain syndromes, notably the piriformis (27, 33). However, the concept is well recognized in regard to nerve involvement with numerous muscles.

Under normal conditions and through normal range of motion, it may be presumed that a muscle will not cause irritation to a nerve that lies in close proximity to it or that pierces it. A muscle that is drawn taut, however, becomes firm and has the potential for exerting a compressive or a friction force. A muscle that has developed adaptive shortness moves through less range and becomes taut before reaching normal length; a stretched muscle moves through more than normal range before becoming taut. A taut muscle, especially a weight-bearing muscle, can cause friction on a nerve during repetitive movements.

In mild cases, the symptoms may be discomfort and dull ache rather than sharp pain when the muscles contract or are elongated. Sharp pain may be elicited by vigorous movements but tends to be intermittent, because the subject finds ways to avoid the painful movements.

Recognizing this phenomenon in the early stages can increase the likelihood of counteracting or preventing the more painful or disabling problems that develop later. Physical therapists who deal with stretching and strengthening exercises have the opportunity to observe early signs of impingement among their patients.

The axillary nerve emerges with the posterior circumflex humeral artery through the quadrangular (quadrilateral) space that is bounded posteriorly by the teres major, latissimus dorsi, long head of the triceps, and humerus. When stretching a tight teres major, a patient may complain of a shooting pain in the area of cutaneous sensory distribution of the axillary nerve (upper lateral cutaneous nerve of the arm). The assumption is that the axillary nerve is being compressed or stretched against the tight teres major. The pain that results from direct irritation to the nerve is in contrast to the discomfort that is often associated with the usual stretching of tight muscles (see cutaneous nerve distribution and teres syndrome).

The femoral nerve pierces the psoas major muscle. During assisted stretching exercises, a patient with tight iliopsoas muscles may complain of pain along the anteromedial aspect of the leg in the area of cutaneous sensory distribution of the saphenous nerve (see cutaneous nerve distribution).

The greater occipital nerve emerges from the suboccipital triangle and superficially pierces the trapezius muscle and fascia. Movements of the head and neck in the direction of contracting or stretching the trapezius may elicit pain in the area of the back of the head and the cervical region (see occipital headache). Other examples include:

- Supinator with radial nerve (27, 34).
- Pronator with median nerve (27, 31, 34).
- Flexor carpi ulnaris with ulnar nerve (23).
- Lateral head of the triceps with radial nerve (27, 34).
- Trapezius with greater occipital nerve (23).

- Scalenus medius with C5 and C6 root of the plexus and long thoracic nerve (23).
- Coracobrachialis with musculocutaneous nerve (27, 31).

Muscle Spasm

Spasm is an involuntary contraction of a muscle or a segment within a muscle that can result from painful nerve stimulation. Irritation of root, plexus, or peripheral nerve branch levels may cause spasm of a number of muscles, whereas spasm caused by irritation of the nerve endings within a muscle may be limited to the muscle involved or be widespread because of reflex pain mechanisms (35).

Treatment of muscle spasm depends on the type of spasm. Relief of spasm resulting from initial nerve irritation of the root, trunk, or peripheral branch must depend on relief of such nerve irritation. Aggressive treatment of the muscle or muscles in spasm will tend to aggravate the symptoms. For example, avoid the use of heat, massage, and stretching of the hamstring muscles in cases of acute sciatica. Rigid immobilization of the extremity is also contraindicated.

Protective spasm may occur secondary to injury of underlying structures, such as a ligament or bone. This protective guarding, such as often occurs following a back injury, prevents movement and further irritation of the injured structure. Protective spasm should be treated by application of a protective support to relieve the muscles of this extraordinary function. Muscle spasm tends to subside rapidly and pain diminishes when a support is applied. As the muscles relax, the support maintains the function of protection to permit healing of whatever underlying injury gave rise to the protective muscle response (36).

Besides the relief from restriction of motion, the support gives added relief by putting pressure on the muscles in spasm. The positive response to direct pressure on the muscle distinguishes this type of spasm from that caused by initial nerve irritation. In the low back, where protective muscle spasm frequently occurs, a brace with a lumbar pad, or a corset with posterior stays bent to conform to the contour of the low back, may be used for both immobilization and pressure.

In most instances, one may assume that the underlying disturbance is severe enough to require the use of a support for at least a few days to permit healing. However, it is not uncommon to find, when the acute onset of pain is caused by a sudden exaggeration of movement, that a rigid posture persists because of the patient's fear of movement rather than because of the continued need for a protective reaction. Because of this possibility, it is often useful to apply heat and gentle massage as a diagnostic aid in determining the extent of protective reaction.

Segmental muscle spasm is an involuntary contraction of the uninjured segment of a muscle as a result of an injury to the muscle. The contraction of this part puts tension on the injured part, and a condition of strain is present. Pain associated with tension within the muscle may be outlined by the margins of the muscle or be widespread because of reflex or referred pain mechanisms. Treatment requires immobilization in a position that relieves tension on the affected muscle. A positive response may also be obtained by gentle, localized massage to the area in spasm.

Muscle spasm associated with tendon injury differs from the above when the tension is exerted on the tendon rather than on a part of the muscle. Tendons contain many nerve endings that are sensitive to stretch, and pain associated with tendon injury tends to be severe.

Adaptive Shortening

Adaptive shortening is tightness that results from the muscle remaining in a shortened position. Unless the opposing muscle is able to pull the segment back to neutral position or some outside force is exerted to lengthen the short muscle, the muscle in question will remain in a shortened condition.

Shortness represents a slight to moderate decrease in muscle length and results in a corresponding restriction of range of motion. It is considered to be reversible, but stretching movements must be done gradually to avoid damaging the tissue structures. A period of several weeks is usually necessary for restoration of mobility in muscles exhibiting moderate tightness.

Wheelchair users and those who frequently maintain a sedentary, seated position may develop adaptive shortening in the one-joint hip flexors (iliopsoas). Prolonged sitting with the knees partially extended places the foot in a position of plantar flexion and may result in adaptive shortening of the soleus. Women who wear high-heeled shoes much of the time may also develop adaptive shortening of the soleus. Such shortness can affect both balance and standing alignment.

Stretch Weakness

Stretch weakness is defined as weakness that results from muscles remaining in an elongated condition, however slight, beyond the neutral physiological rest position but not beyond the normal range of muscle length. The concept relates to the duration rather than the severity of the faulty alignment. (It does not refer to overstretch, which means beyond the normal range of muscle length.)

Many cases of stretch weakness have responded to treatment that supported the muscles in a favorable position, although the muscles had been weak or partially paralyzed for a long time even several years after the onset of the initial problem. Return of strength in such instances indicates that damage to the muscles was not irreparable.

A familiar example of stretch weakness superimposed on a normal muscle is the foot drop that may develop in a bedridden patient as a result of bed linens holding the foot in plantar flexion. Weakness in the dorsiflexors results from the continuous stretch on these muscles even though there is no neurological involvement.

Stretch weakness superimposed on muscles affected by anterior horn cell involvement was seen numerous times in patients with poliomyelitis (see example, Appendix B).

Stretch weakness superimposed on a lesion of the CNS has been observed in patients with multiple sclerosis, especially with regard to the wrist extensors and ankle dorsiflexors. Stretching opposing muscles that have become shortened and applying a support in the form of a cock-up splint for the wrist or an orthosis for the ankle have resulted in improved strength and functional ability.

Stretch weakness of a less dramatic nature is frequently seen in cases of occupational and postural strain. The muscles most often affected have been one-joint muscles: gluteus medius and minimus, iliopsoas, hip external rotators, abdominal muscles, and middle and low trapezius.

Muscles exhibiting stretch weakness should not be treated by stretching or movement through the full range of joint motion in the direction of elongating the weak muscles. The condition has resulted from continuous stretching, and it responds to immobilization in a physiological rest position for a sufficient period of time to allow recovery to occur. Realignment of the segment, bringing it into a neutral position, and use of supportive measures to help restore and maintain such alignment until weak muscles recover strength are important factors in treatment. Any opposing tightness that tends to hold the segment out of alignment must be corrected to relieve tension on the weak muscles. Faulty occupational positions that impose continuous tension on certain muscles must also be adjusted or corrected. Care must be taken not to overwork a muscle that has been subjected to a prolonged tension stress. As the muscles improve in strength and become capable of maintaining the gain, the patient is expected to use the muscles by working to maintain proper muscle balance and good alignment.

SECTION V
TREATMENT FUNDAMENTALS

See Box 1-3 for guidelines for clinicians.

STABILITY OR MOBILITY

In the treatment of conditions affecting joints and muscles, one must determine the overall objectives of treatment based on whether **stability** or **mobility** is the desired outcome for optimal function. Joint structures are designed so that along with greater mobility there is less stability, and along with greater stability there is less mobility.

It is generally accepted that along with growth from childhood to adulthood, a tightening up of the ligamentous structures occurs, along with a corresponding decrease in flexibility of the muscles. This change affords greater stability and strength for adults than for children.

Individuals with ligamentous laxity may demonstrate less stability than an individual with less flexibility. A knee that goes into hyperextension, for example, is not mechanically as stable for weight bearing as one that is held in neutral extension.

Lack of stability of the spine in a flexible individual can lead to problems when work requires prolonged sitting, standing, or the need to lift and carry heavy objects. Muscles do not succeed in functioning for both *movement* and the *support* normally afforded by the ligaments. When symptoms occur, they will appear as fatigue first and only later as pain. A young adult with excellent strength but excessive spinal flexibility may require a back support to relieve painful symptoms.

From a mechanical standpoint, two types of faults relate to *alignment* and *mobility*: undue compression on articulating surfaces of bone and undue tension on bones, ligaments, or muscles. Eventually, two types of bony changes may occur: Excessive compression produces an eroding effect on the articulating surface, whereas tension may result in bony hypertrophy at the point of connective tissue or muscle attachments.

Lack of mobility is closely associated with persistent faulty alignment as a factor in causing undue compression. When mobility is lost, stiffness occurs, and a certain alignment remains constant. This may be a result of the restriction of motion by tight muscles or of the inability of weak muscles to move the segment through the arc of motion. Muscle tightness is a constant factor, tending to maintain the segment in faulty alignment regardless of the position of the body. Muscle weakness is a less constant factor because changing the body position can bring about a change in the alignment of the segment. With normal movement in joints, wear and tear on the joint surfaces tends to be distributed; however, with limitation of range, the wear will take place only on the joint surfaces that represent the arc of use. If the segment that is restricted by muscle tightness is protected against any movement that may cause strain, the other parts that must compensate for such restriction can become susceptible to strain.

BOX 1-3

Guidelines for the Clinician

- Be guided by the age-old adage: "Thou shalt do no harm."
- Obtain the patient's confidence and cooperation.
- Listen carefully to the patient.
- Observe posture, body language, and spontaneous movements that provide helpful diagnostic clues.
- Apply basic knowledge of anatomy, physiology, and body mechanics in musculoskeletal evaluations and treatments of patients.
- Consider whether the occupational or recreational activities of the patient alleviate or aggravate existing conditions.
- Educate your patients; help them to understand the nature of their problems.
- Be guided by the patient's reaction to previous treatments.
- Be patient with your patients. It often takes more than one session to overcome anxiety and guarding against pain.
- Start treatments in a gentle manner.
- Remember that it is essential to obtain patient relaxation before attempting to stretch tight muscles. Stretching that is too vigorous will retard rather than hasten recovery.
- Understand that muscles weakened as a result of injury or disease must be handled with more care than a muscle exhibiting normal function.
- When applying traction, use a firm but gentle grasp. Avoid pinching, twisting, or pulling the skin over the segment that is being held.
- Expect that favorable responses to treatment will progress gradually, based on the patient's tolerance to pain or discomfort.
- Avoid the attitude of "more is better." Reactions to treatment are often delayed, so one may not know until the next day that the previous treatment was "too much."
- Avoid application of heat over areas with impaired sensation or circulation, and over muscles exhibiting stretch weakness.
- Recognize that continuation of treatment is contraindicated if any of the following symptoms appear: swelling, redness, abnormal temperature of the region, marked tenderness, loss of range of motion, or persistent pain.
- Involve the patient in setting treatment goals and in planning a home treatment program.
- Be accountable. Document your assessment, evaluation, treatment plan, and follow-up care.

Excessive joint mobility results in tension on the ligaments that normally limits range of motion and can result in undue compression on the margins of the articulating surfaces when the excessive range is long-standing or frequent.

ROLE OF MUSCLES IN SUPPORTING THE SKELETON

In addition to their role in movement, muscles have an important role in supporting the skeletal structures. A muscle must be long enough to permit normal mobility of the joints yet short enough to contribute effectively to joint stability.

When range of motion is limited because of tight muscles, treatment consists of the use of various modalities and procedures to promote muscle relaxation and optimal length. Stretching exercises should be gradual, and although they may cause mild discomfort, they should not cause pain.

When range of motion is excessive, care must be taken to avoid overstretching. If the patient has excessive mobility, with or without pain, in many instances it is prudent to apply a support that can allow the affected structures to tighten. It may or may not be necessary to add specific exercises, because many muscles that are weakened by stretching recover with normal activity when overstretching is avoided.

TREATMENT OPTIONS

Following are treatment options which may be employed in the care of patients presenting with impairments of posture and pain (see Table 1-4). This is not intended to be an exhaustive, all-encompassing list. Greater detail may be provided in later chapters as appropriate.

TABLE 1-4 Treatment Options Used for Impairments of Posture and Pain

Treatment	Definition	Effects
Traction	• A force used therapeutically to produce elongation or stretch of joint structures and/or muscles. Properly applied, the force pulls in the direction perpendicular to the articulating surfaces of a joint. Traction may be applied: • Manually, • using a mechanical traction device, • static weights, or positional distraction.	• Relief of pain and spasm • Reduction/prevention of adhesions • Stretching of tight musculature • Improved circulation
Massage	**Manual therapy** techniques are skilled hand movements and skilled passive movements of joints and soft tissue. Techniques may include: • manual lymphatic drainage, • manual traction, • massage, • mobilization/manipulation, and • passive range of motion.	• Improve circulation • Promote relaxation of muscles • Loosen scar tissue • Stretch tight muscles/fasciae • Relieve edema/swelling • Improve tissue extensibility • Increase range of motion • Mobilize/manipulate soft tissue and joints • Modulate pain • Reduce restriction
Exercise (19, 31)	*Therapeutic exercise* is the systematic performance or execution of planned physical movements or activities intended to enable the patient or client to remediate or prevent impairments of body functions and structures, enhance activities and participation, reduce risk, optimize overall health, and enhance fitness and well-being. Therapeutic exercise may include aerobic and endurance conditioning and reconditioning; agility training; body mechanics training; breathing exercises; coordination exercises; developmental activities training; muscle lengthening; movement pattern training; neuromotor development activities training; neuromuscular education or reeducation; perceptual training; range of motion exercises and soft tissue stretching; relaxation exercises; and strength, power, and endurance exercises.	• Enhance bone density • Enhance breathing • Enhance/maintain physical performance • Improve safety • Increase aerobic capacity/endurance • Increase muscle strength, power, and endurance • Enhance postural control and relaxation • Increase sensory awareness • Increase tolerance of activity • Prevent or remediate impairments in body functions and structures, activity limitations, and participation restrictions to improve physical function • Enhance health, wellness, and fitness • Reduce complications, pain, restriction, and swelling • Reduce risk and increase safety during activity performance • Strengthen weak muscles • Lengthen short muscles for the purpose of restoring the elasticity on which normal muscle function depends • Increase endurance • Improve coordination • Restore function • Stimulate circulation
Supports	• Correction of alignment faults associated with weakness often requires supportive measures. • Inclusive of orthotic/prosthetic positioning technologies intended to improve positioning and function	• Immobilize • Minimize pain • Correct faulty alignment • Relieve strain on weak muscles • Facilitate function • Restrict movement
	Modalities	
Electrical Stimulation	• A technique used to elicit a muscle contraction using electrical impulses	• Modulate pain • Reeducate muscle • Manage Edema • Decrease inflammation
Heat (32)	• A form of thermal energy transfer from a heating agent to a body segment	• Pain and muscle spasm relief • Decrease joint stiffness • Increased extensibility of collagen tissue • Increased blood flow • Resolution of inflammatory infiltrates (32) • Facilitate stretch
Cold (32)	A form of thermal energy transfer from a body segment to a cooling agent	• Reduce pain and swelling/edema • Inhibit spasticity • Facilitate muscular contraction for various forms of neurogenic weakness • Muscle reeducation

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