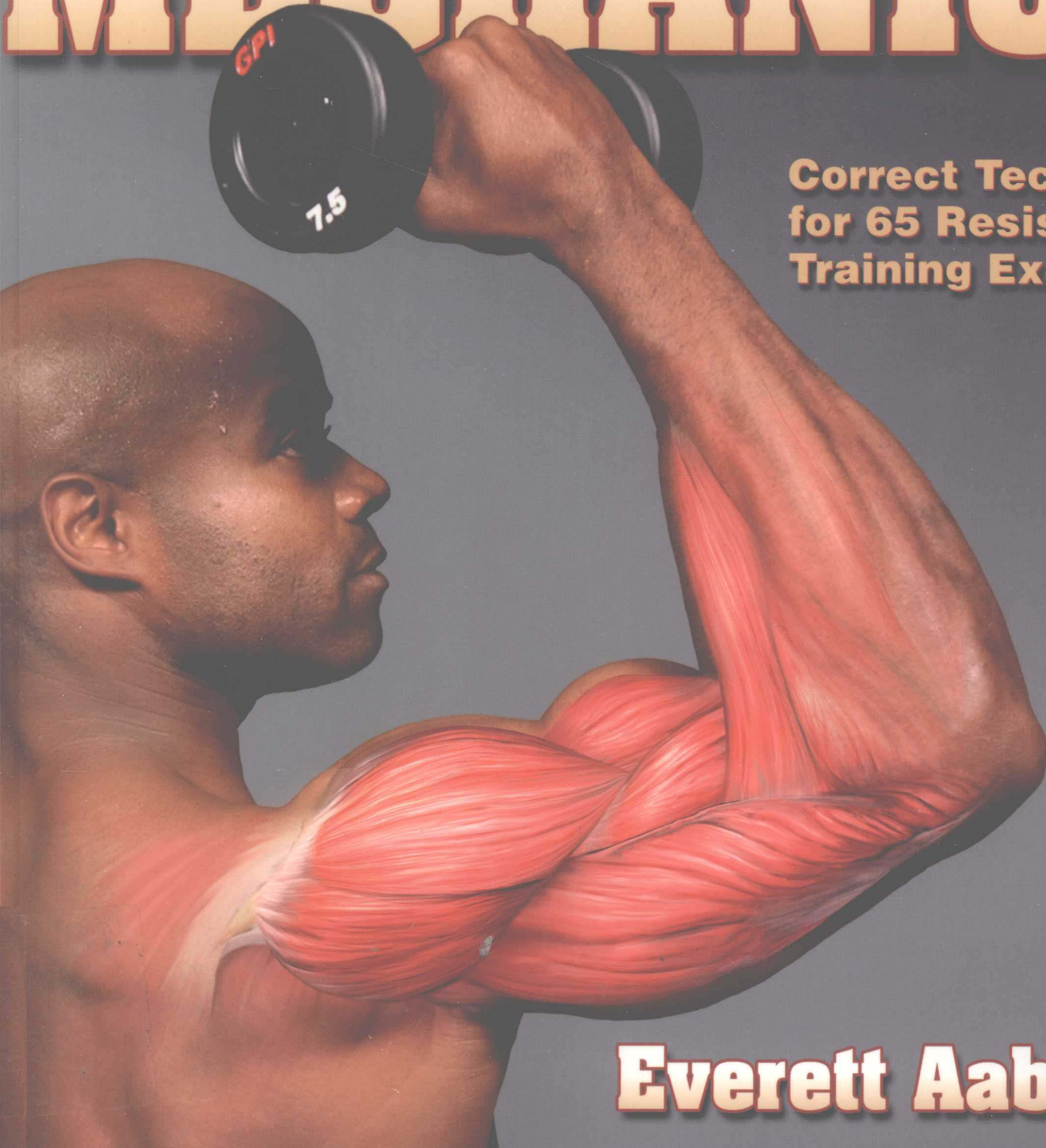
SECOND EDITION

MUSCLE MECHANICS



Correct Technique for 65 Resistance Training Exercises

Everett Aaberg

Muscle Mechanics

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Human Kinetics
Web site: www.HumanKinetics.com

United States: Human Kinetics
P.O. Box 5076
Champaign, IL 61825-5076
800-747-4457
e-mail: humank@hkusa.com

Canada: Human Kinetics
475 Devonshire Road Unit 100
Windsor, ON N8Y 2L5
800-465-7301 (in Canada only)
e-mail: orders@hkcanada.com

Europe: Human Kinetics
107 Bradford Road
Stanningley
Leeds LS28 6AT, United Kingdom
+44 (0) 113 255 5665
e-mail: hk@hkeurope.com

Australia: Human Kinetics
57A Price Avenue
Lower Mitcham, South Australia 5062
08 8277 1555
e-mail: liaw@hkaustralia.com

New Zealand: Human Kinetics
Division of Sports Distributors NZ Ltd.
P.O. Box 300 226 Albany
North Shore City
Auckland
0064 9 448 1207
e-mail: info@humankinetics.co.nz

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HUMAN KINETICS

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Preface

Over the last two decades, resistance training has drastically risen in popularity and demand. Health clubs, racquet clubs, country clubs, hotels, apartment complexes, hospitals, and even corporate wellness centers have been gradually dedicating more space, buying more equipment, and devoting more attention to providing resistance training for their patrons and employees. A remarkable amount of research that documents the numerous health benefits associated with resistance training has been amassed. Information on these benefits has emerged in professional textbooks as well as commercial and consumer books and overflowed into magazines of all kinds. The mounting facts regarding resistance training's potential to improve health and human performance, along with its ability to sculpt the human physique more than any other modality of exercise, ensure that this trend will continue to grow in the coming years.

However, if you want to accomplish any goal with resistance training—whether the aim is rehabilitation, optimal athletic performance, bodybuilding, fat loss, or simply overall health—efficient exercise selection and optimal technique are critical for success. This fact is confirmed by most fitness professionals, yet there are still very few books available that present sound scientific rationale for the exercise selections and techniques that they present. As a result, people who are actively attempting to gain improvements from resistance training are left with little direction for selecting the best exercises to accomplish their goals, and even less information on what exactly constitutes efficient and safe exercise technique.

Deciding what criteria should be used in determining "efficient" or "safe" technique for resistance training is often a topic for debate and seems to be extremely subject to opinion. However, an enormous amount of scientific data exists on which to base many elements of resistance training technique. Through in-depth study of anatomical design and specific joint structure, we can deduce much in regard to the body's intended functional abilities and also its natural limitations. This information combined with the application of basic physics and biomechanics can assist in developing definite guidelines for selecting and performing resistance training exercises for more efficiency and reduced risk.

The primary purpose of *Muscle Mechanics* is to teach efficient and safe exercise technique and to provide you with the scientific information necessary for better selecting resistance exercises and designing resistance training programs in order to achieve all of your performance and aesthetic goals.

Muscle Mechanics presents many contemporary resistance training exercises aimed at improving biomechanical function and movement performance but also includes several traditional exercises that are time proven for their effectiveness in developing the physique. However, all the resistance training exercises (both traditional and contemporary) have been analyzed and modified, through application of the scienctific principles and infusion of the specialized techniques presented in this book. Previous versions of this book have served as instructional texts in several colleges and universities and as an instruction manual for many fitness organizations around the world such as the renowned Cooper Institute. Thousands of professional trainers have taught and successfully used many of the exercises and associated techniques presented in this text to better develop the abilities and aesthetics of their clients and themselves. Learn and apply the information herein. Integrate the exercises and use the techniques with confidence, but always check with your doctor before beginning any exercise program.

Contents

1

CHAPTER

Anatomical Design and Function

Muscle Mechanics focuses on providing instruction on a collection of the safest and most efficient resistance training exercises possible based on the structure and function of the human body. Therefore, before learning any specific exercises and techniques for improving the performance or the aesthetics of the body, you should first gain a general understanding of how the body is constructed and designed to move. The human body is an extremely sophisticated machine with a very large number of components that combine to produce an infinite variety of postures and movements. These components are highly integrated and function together as interdependent systems and subsystems.

A contemporary view of functional anatomy often presented by authors and experts describes the body as being composed of three basic interdependent systems. These three systems are referred to as the *control system* (or sensorimotor system), the *active system* (or muscular system), and the *passive system* (or skeletal system). All three systems must work together synergistically to produce any motion or even to just stabilize the body in the presence of outside forces such as gravity. Therefore, since all exercise requires unique combinations of both movement and stabilization, any exercise will impress a training effect on all three systems, not just the targeted muscles. This makes technique more critical than many people realize. Every exercise performed will not only affect the body's "hardware," which consists of the joints and muscles of the active and passive systems, but will also imprint information on the "software," which consists of the programmable features of the control system.

To perform any body movement, whether voluntarily or through reflex actions, the control system issues commands to the active system to initiate the unique concert of muscle actions necessary for stabilizing and moving the passive system. These three systems are truly interdependent such that even automated actions such as breathing, coughing, sneezing, or flinching in response to pain all require specific integrated and coordinated actions. The following sections cover the movement responsibilities of each system, beginning with the passive-skeletal system, then the active-muscular system, and then the control-sensorimotor system. Figure 1.1 shows a schematic representation of these three systems and their interdependent relationships.

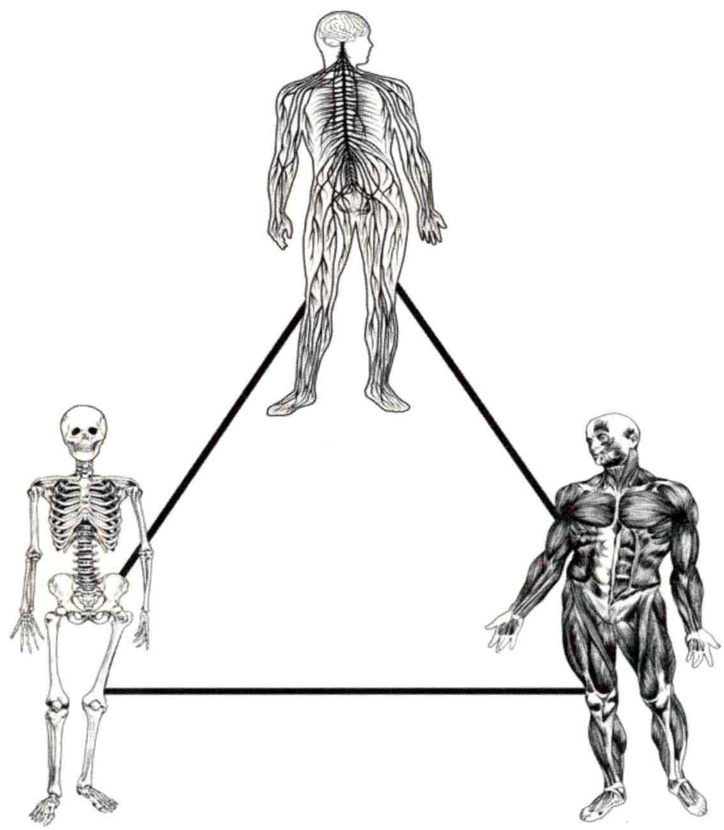


Figure 1.1 The three systems of human movement.

The Passive System

The passive system is composed of the skeleton, joints, and associated connective tissues. It is termed "passive" because there is no force directly produced by this system. It is a reactive system that can only transfer forces produced by the active system as commanded by the control system. The passive system provides the structures and levers that give us the ability to utilize internal forces to move the body and interact with the environment.

The Skeleton

At birth, the human body contains approximately 270 bones, some of which are designed to fuse as the body grows. By the time a person becomes an adult, the skeleton normally consists of only 206 bones, which provide a lightweight yet protective and supportive structure that ultimately provides for all movement of the body. Figure 1.2 details the construction of the human skeleton for easy reference. The skeleton performs three main mechanical functions:

1. It protects certain organs such as the brain, spinal cord, heart, and lungs.
2. It acts as a supportive framework for the body.
3. It acts as a system of levers that the muscles can act on to stabilize and move the body.

1. Cranium
2. Clavicle
3. Sternum
4. Rib
5. Humerus
6. Radius
7. Ulna
8. Pubis
9. Carpus
10. Metacarpals
11. Phalanges
12. Femur
13. Patella
14. Tibia
15. Fibula
16. Tarsus
17. Metatarsals
18. Phalanges
19. Cervical vertebrae (7)
20. Scapula
21. Thoracic vertebrae (12)
22. Lumbar vertebrae (5)
23. Illium
24. Sacrum
25. Ishium

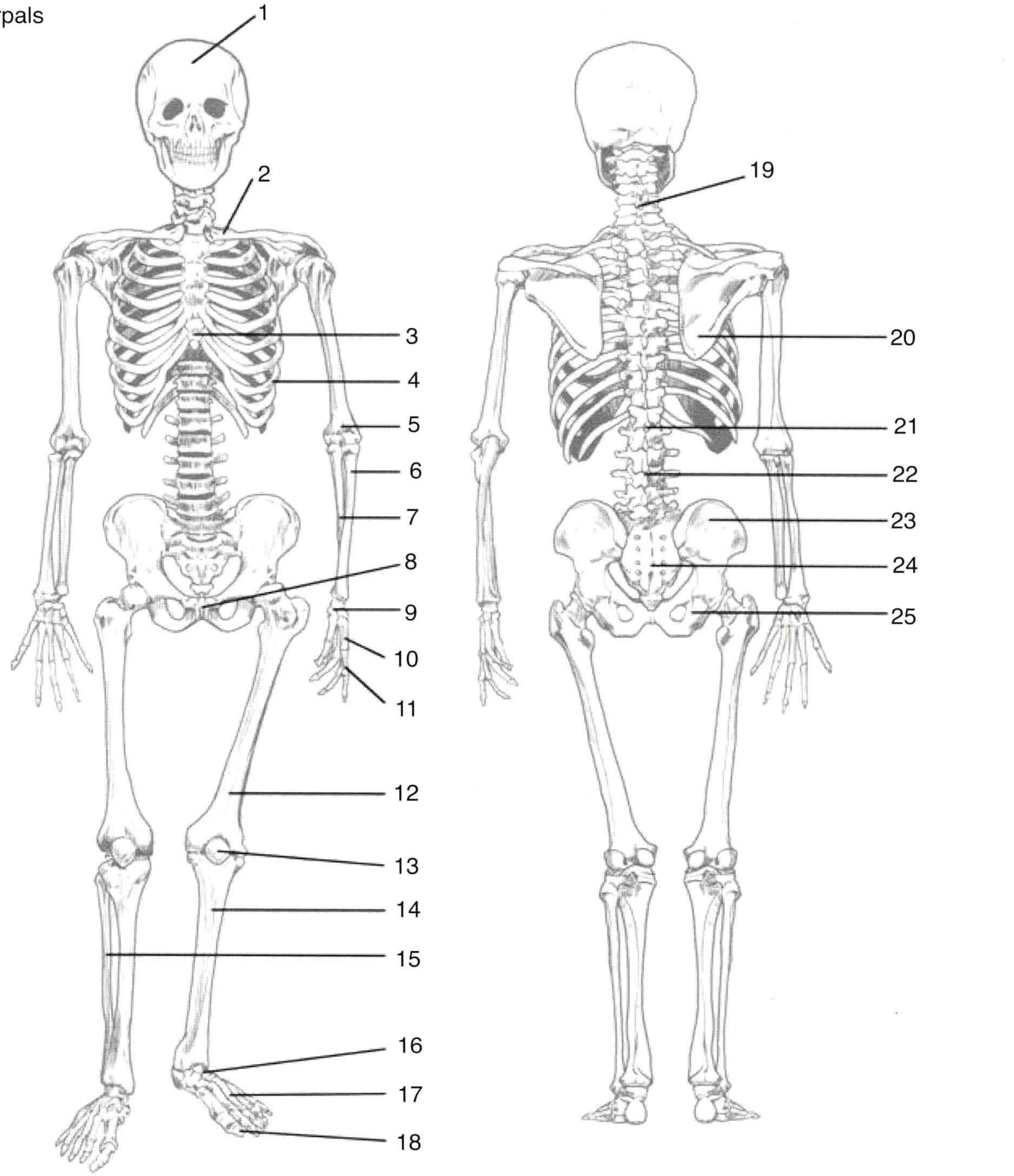


Figure 1.2 The passive-skeletal system.

The bones of the skeleton are typically divided into two main groups, the axial skeleton and the appendicular skeleton. The adult *axial skeleton* is composed of approximately 80 bones that form the skull, spine, and rib cage. It provides the foundation for the body and protects the brain, spinal cord, and major organs. The *appendicular skeleton* is composed of 126 bones that make up the scapula and the upper limbs as well as the pelvis and the lower limbs. This collection of bones provides the primary lever systems that enable a person to move the body and any external objects.

The Joints

Joints are, simply stated, the meeting place of two or more bones. The bone endings, the associated connective tissues that hold them together, and the sensory receptors in and around the joint are all vital components of the passive-skeletal system. Joints are uniquely designed to allow for certain amounts and directions of movement while also providing certain levels of stability. There are three structural classifications of joints, each with distinct levels of possible articulation, or available movement: fibrous, cartilaginous, and synovial joints.

Fibrous joints allow for very little, if any, movement because of the small amount of space between bone endings. They include the joints of the skull, the joints between the radius and ulna of the lower arm, and the distal connection of the fibula and tibia of the lower leg.

Cartilaginous joints allow for some movement, but their capacity for movement is limited because of the proportionally higher collagen to elastin fiber compositions of these joints. Examples of cartilaginous joints are those that connect the ribs to the sternum.

Synovial joints account for most of the joints of the human body, and they are individually designed with considerable variance in their range of motion. The three types of synovial joints are categorized by the number of directions in which they can rotate around a given axis: uniaxial, biaxial, and multiaxial joints (see figure 1.3, a-c).

Uniaxial joints have only one direction of rotation and operate much like a hinge. The elbow and the phalangeal joints of the fingers are examples of uniaxial joints. *Biaxial joints,* such as the wrist, ankle, and knee (when flexed), allow for movement in two perpendicular planes. *Multi-*

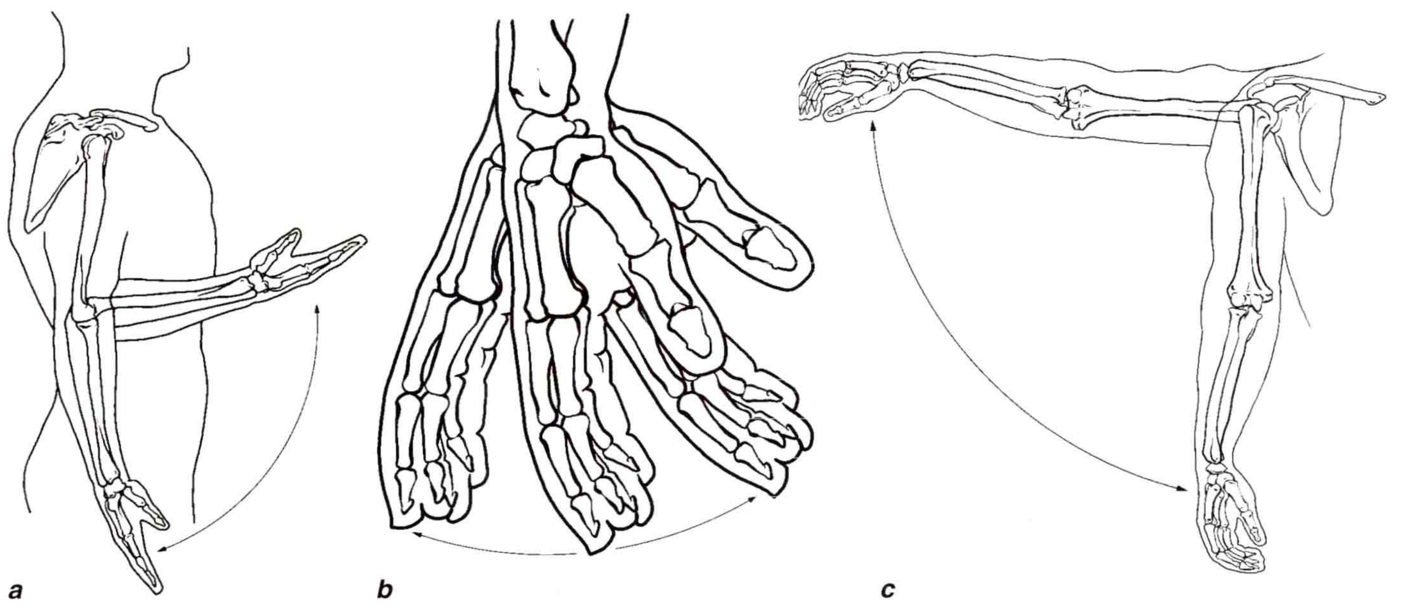


Figure 1.3 Examples of the three types of synovial joints: *(a)* uniaxial, *(b)* biaxial, and *(c)* multiaxial.

axial joints, such as the shoulder and hip, allow for movement in all three planes of motion and therefore provide us with the greatest degrees and varieties of possible movement.

Passive Connective Tissue

A joint's capacity for movement is only in part determined by the structure and congruence of the bones themselves. Connective tissues hold the bones together and regulate the type, direction, and range of motion between the bone endings. Two types of passive connective tissues that assist with stabilization and regulation of joint movement are ligaments and joint capsules.

Ligaments connect bone to bone and consist primarily of strong collagen fibers arranged parallel to each other with only small amounts of elastic fiber. They are designed to restrict joint movement within specific directions and within specific ranges of movement. Ligaments are not capable of any significant stretching without deformation or tearing. Therefore, they are at risk when movement is forced at a joint in directions or at ranges outside their genetically determined limits. Ligaments can be separate or can be part of the joint capsule, and they can be located outside or inside the capsule itself. Ligament placement and design are relative to the designed function of the joint and its combined needs for mobility and stability.

Joint capsules enclose the joint, creating a cavity that holds fluid in the joint and also assists in the transfer of forces from bone to bone. The capsule is typically composed of two or more layers of regular collagenous tissue that form a sleeve around the joint. The parallel collagen fiber arrangements of each layer are typically laid down at different angles to the adjacent layers. This enables the capsule to allow for movement in certain directions and still strongly resist movement in other directions. Capsules assist with joint stability and can tear or become deformed when overstretched.

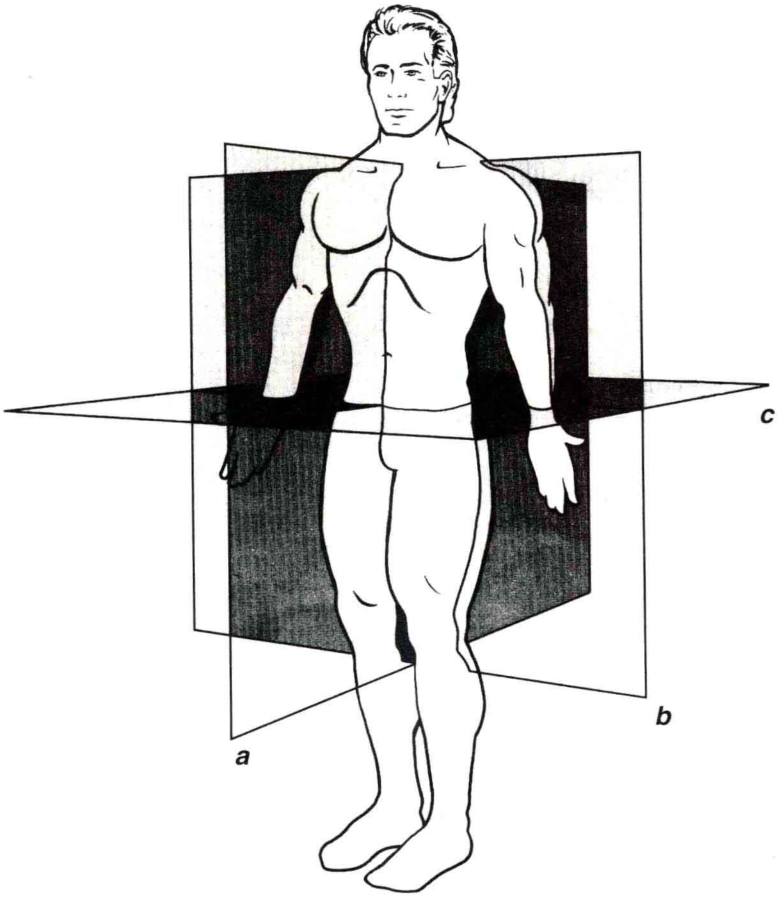
Cartilage is another substance found at synovial joints. It does not play a connective role but should also be considered when analyzing joint movement and joint forces. Cartilage can also be damaged as a result of excessive joint movement or through exposure to high or frequent compressive, distractive, or shearing forces. Cartilage damage is often permanent and can occur suddenly or gradually depending on the range, force, or repetition of joint motion.

Hyaline or *articular cartilage* is a smooth, slick protective covering over bone endings at synovial joints that assists with ease of joint movement. Articular cartilage is well constructed to absorb certain levels of force and friction, but excessive pressure, repetitive mechanical wear, or movement exceeding the designed limits of the joint can all contribute to degeneration of articular cartilage, which can lead to osteoarthritis. Once osteoarthritis begins in a joint, it typically continues to deteriorate joint surfaces, causing inflammation, pain, and decreased joint function.

Fibrocartilage contains high concentrations of collagenous fibers and is specially designed for absorbing shock. It is a thick, rubberlike material found in the vertebral discs of the spine, the menisci of the knee, the pubis symphysis of the pelvis, and at other joints in need of the extra cartilage support or padding between bone surfaces. Though resilient, fibrocartilage is also susceptible to thinning, tearing, folding, and rupturing under high levels of, or frequent exposure to, impact forces and friction. The body's natural replacement of fibrocartilage is limited, which can often leave the joint with little or no disc substance and painful, inefficient joint movement.

Isolated Joint Mechanics

Any movement of a joint requires interaction of all three systems and is not just a result of the muscles pulling on bones. The human body is also capable of producing an infinite number of joint movements that do not occur in any singular plane. However, for the purpose of



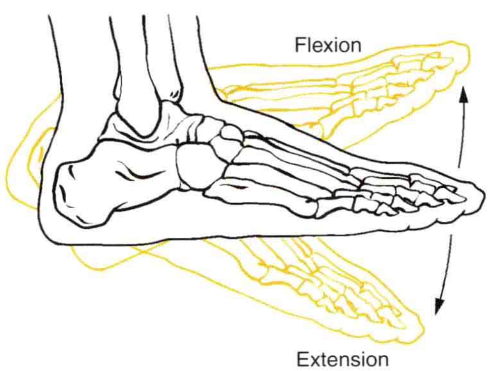
establishing a better understanding of basic muscle mechanics, joint motion will be presented in a traditional "three-plane format" (median, frontal, and horizontal) as pictured in figure 1.4, and the information will incorporate the following premises:

- The joint movement is beginning from a preset anatomical standing position.
- Each joint movement is considered in isolation and is performed in only one general plane of motion.
- Only the muscles directly involved with the specific movement of that joint are recognized.

Figure 1.4 The planes of motion: *(a)* the median plane, *(b)* the frontal plane, and *(c)* the horizontal plane.

Joint Motions of the Median Plane

The median plane, also known as the sagittal plane, divides the body down the middle into left and right halves. Most human movement takes place predominantly in the median plane. The joint motions of flexion and extension are the primary movements of the median plane and occur at the ankle, knee, hip, spine, shoulder, elbow, wrist, and neck. Scapular protraction and retraction are also considered median plane movements.

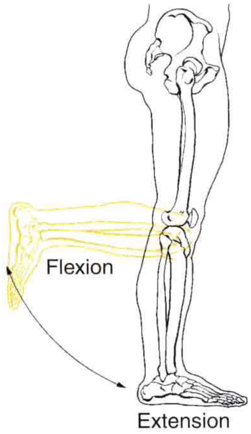


Ankle Flexion (Dorsiflexion)

Tibialis anterior
Extensor hallucis longus
Extensor digitorum longus
Peroneus tertius

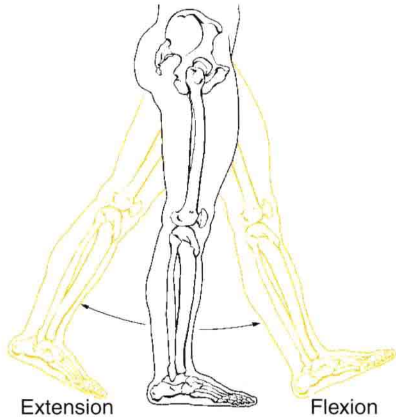
Ankle Extension (Plantar Flexion)

Peroneus longus
Peroneus brevis
Triceps surae
Flexor hallucis longus
Tibialis posterior
Flexor digitorum longus



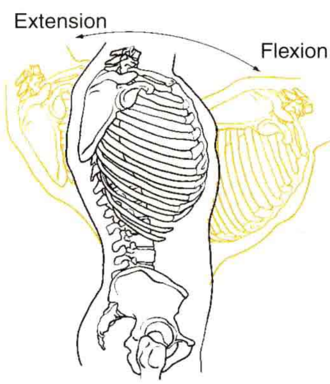
Knee Flexion
Biceps femoris (long and short heads)
Semitendinosus
Semimembranosus
Popliteus
Gastrocnemius
Sartorius
Gracilis

Knee Extension
Vastus lateralis
Vastus medialis
Vastus intermedius
Rectus femoris
Tensor fasciae latae
Gluteus maximus (superficial portion)



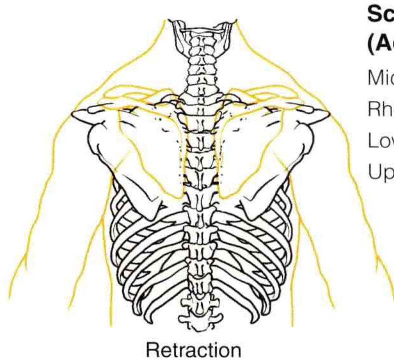
Hip Flexion
Psoas
Iliacus
Rectus femoris
Tensor fasciae latae
Gluteus minimus and medius (anterior portions)
Sartorius
Pectineus
Gracilis

Hip Extension
Gluteus maximus
Biceps femoris (long head)
Semimembranosus
Semitendinosus
Gluteus medius (posterior portion)
Adductor magnus

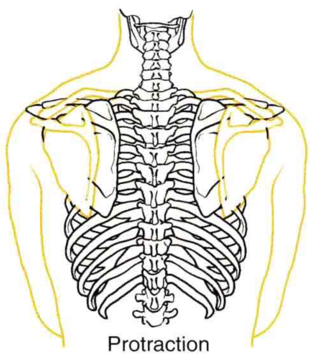


Trunk Flexion
Rectus abdominis
External obliques (bilateral contraction)
Internal obliques (bilateral contraction)

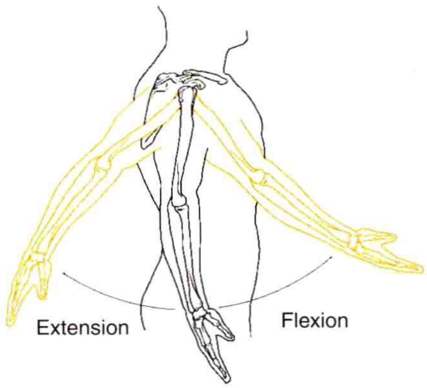
Trunk Extension
Spinalis group
Longissimus group
Iliocostalis group
Transversospinalis group
Interspinalis



Scapular Retraction (Adduction)
Mid trapezius
Rhomboids
Lower trapezius
Upper trapezius



Scapular Protraction (Abduction)
Mid serratus anterior
Upper serratus anterior (superior)
Lower serratus anterior (inferior)

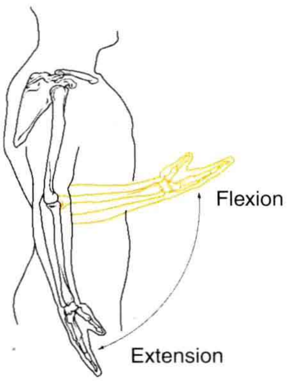


Shoulder Flexion

Anterior deltoid
Pectoralis major
Coracobrachialis

Shoulder Extension

Latissimus dorsi
Posterior deltoid
Teres minor

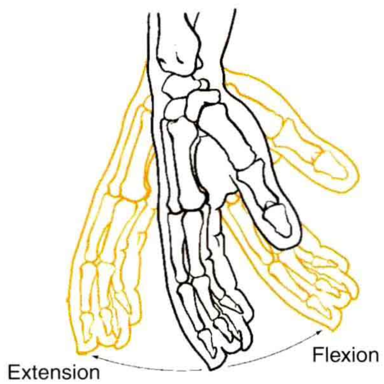


Elbow Flexion

Biceps brachii
Brachioradialis
Brachialis

Elbow Extension

Triceps long head
Triceps lateral head
Triceps medial head (deep head)
Anconeus

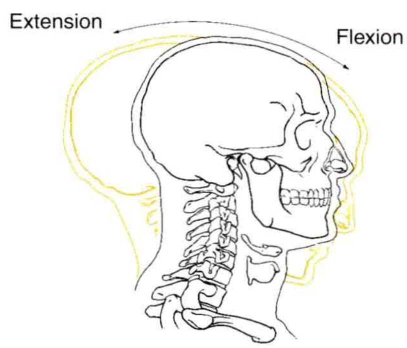


Wrist Flexion

Flexor carpi radialis
Palmaris longus
Flexor carpi ulnaris

Wrist Extension

Extensor carpi radialis longus
Extensor carpi radialis brevis
Extensor carpi ulnaris



Neck Flexion

Longus colli (bilateral contraction)
Rectus capitis (bilateral contraction)
Longus capitis (bilateral contraction)
Sternocleidomastoid (bilateral contraction)
Suprahyoid group (accessory)
Infrahyoid group (accessory)

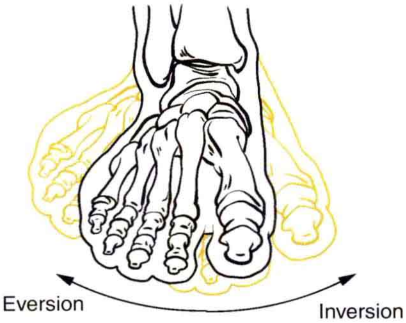
Neck Extension

Splenius capitis (bilateral contraction)
Splenius cervicis (bilateral contraction)
Spinalis capitis (bilateral contraction)*
Semispinalis capitis (bilateral contraction)*
Spinalis thoracis
Levator scapulae (bilateral contraction)
Trapezius (bilateral contraction)

*When spine is fixed or stabilized

Joint Motions of the Frontal Plane

The frontal plane, sometimes presented as the coronal plane, divides the body through the side into front and back halves. Joint movements of the frontal plane include abduction and adduction of the wrist, shoulder, and hip; inversion and eversion of the ankle; scapular elevation, depression, upward rotation, and downward rotation; and lateral flexion of the spine and neck.

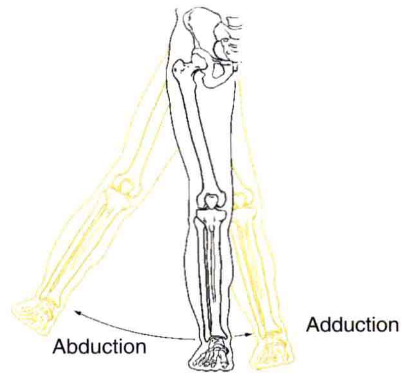


Ankle Inversion (Partial Supination)

Extensor hallucis longus
Tibialis anterior
Tibialis posterior
Flexor digitorum longus
Flexor hallucis longus
Triceps surae

Ankle Eversion (Partial Pronation)

Peroneus longus
Peroneus brevis
Peroneus tertius
Extensor digitorum longus (lateral portion)

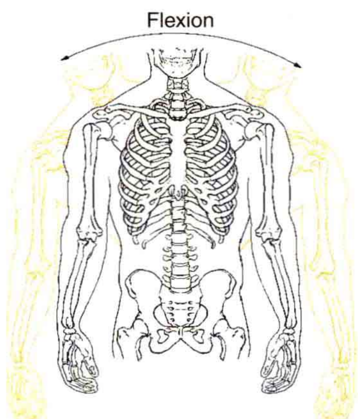


Hip Adduction

Adductor magnus
Adductor longus
Adductor brevis
Pectineus
Gracilis
Psoas
Iliacus

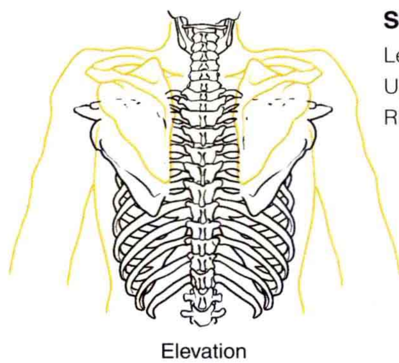
Hip Abduction

Gluteus medius
Gluteus minimus
Tensor fasciae latae
Gluteus maximus (superficial portion)
Piriformis
Obturators
Gemelli
Sartorius



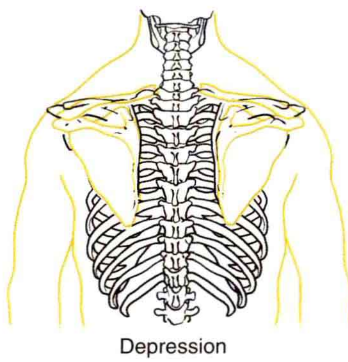
Trunk Lateral Flexion

Internal obliques (unilateral contraction)
Quadratus lumborum (unilateral contraction)
Rectus abdominis (unilateral contraction)
Erector spinae groups (unilateral contraction)
Latissimus dorsi (unilateral contraction)
Transversospinalis group (unilateral contraction)
Intertransversarii (unilateral contraction)



Scapular Elevation

Levator scapulae
Upper trapezius
Rhomboids



Scapular Depression

Lower trapezius
Lower serratus anterior
Pectoralis minor
Subclavius (via the clavicle)