Structure and Function of Skeletal Muscle and the Locomotor System

Skeletal muscles form the major part of the active locomotor system in humans (approximately 10% of body weight), alongside the passive locomotor system (the bony skeleton and joints). In male adults, ~40% of the muscle mass accounts for ~28 kg of normal body weight (70 kg). In newborns, the muscle mass amounts to ~20% of total body weight at birth. In athletes, however, the muscle mass may increase to up to 65% of normal body weight.

The human body contains ~640 individual skeletal muscles with ~220 specific muscles, with various sizes, shapes, and locations or fiber architecture (Kunsch and Kunsch 2005). Some muscles are quite long (e.g., the sartorius muscle at the thigh, 40 cm), while others are more broad (e.g., the latissimus dorsi on the back) or rather powerful and fleshy (e.g., the gluteus maximus at the hip). The smallest muscle in the body, the stapedius in the middle ear (< 1 mm), is attached to the stapes, the last of three small middle ear bones, which act as a cushioning or damping control unit to support the mechanical transfer of acoustic impulses from the eardrum (tympanum) to the inner ear structures (oval window of the cochlea). Some muscles are characterized by a high level of endurance and strength (e.g., the triceps surae and the masseter), while others are used for fine tuning of movements (e.g., the extraocular muscles and the palmar interossei and lumbrical muscles in the hand). In more region-specific muscles such as the facial expression muscles, the small fibers can be used for emotional expression and nonverbal communication. Along with the muscles of the tongue, throat, and diaphragm, the facial expression muscles do not primarily belong to the active locomotor apparatus, although in terms of type and origin they can be classified as skeletal muscle.

Note

In sports, defined muscle groups show an increase in muscle mass (hypertrophy) following heavy exercise and can therefore be used in various types of competition for short-duration power generation (e.g., sprinting, jumping, weightlifting) or else for endurance strength (e.g., middle-distance and long-distance running, marathons, swimming, soccer).

Together with the bones (levers) and joints (centers of rotation), the muscles are regarded as damping units in the lever system to help control performance in the weight-bearing musculoskeletal apparatus. For example, if you jump from a chair, the muscles in the thigh and calf that course over the ankles, knees, and hip joints are able to contract muscle by muscle in accordance with a typical pattern known as a "closed muscle chain" to cushion the gravitational load forces generated by the body's weight after the feet hit the floor. This coordinated motion mechanism makes it possible to stabilize the body's posture considerably and generally helps prevent injuries.

By definition, a muscle is attached by its tendon to the bone at its origin (usually proximal to the joint, known as the *origin*) and at its insertion point (usually distal to the same joint, known as the *insertion*). A muscle can run over a single joint, in which case it is known as a single-joint muscle (e.g., the brachialis), or over two or more joints, in which case it is known as a two-joint or multi-joint muscle (e.g., the biceps brachii). The human body contains more than 220 joints (Kunsch and Kunsch 2005) that can be moved by muscle contraction and are referred to as synovial joints, composed of two bony partners with an articular surface cartilage, cleft, and capsule; or as fibrous, cartilaginous, or bony joints, composed of sustainable jointlike structures in which the space between the bony partners (the cleft) is filled with either fibrous material (known as syndesmosis, interosseous ligament), fibrocartilage (known as synchondrosis, symphysis, intervertebral disks), or even bone material (known as synostosis, cranial sutures). Muscle contractions in freely mobile synovial joints result in either gliding, rotating, or angular movements, or combinations of these (diarthrodial function), depending on the design of the joint, whereas muscle contraction may only cause slight mobility in synarthrodial joints, which are mostly needed to support flexibility or stabilization in defined movement segments along the body axis (e.g., sternocostal joints, intervertebral disks, symphysis) or may be almost immobile, as in the cranial sutures.

Muscle contraction causes flexion or bending that brings the two bones closer together—for example, when bending the neck or trunk forward, a movement that is usually performed in the frontal plane (**Table 1.1**). For example, both arms and thighs are flexed when they are lifted anteriorly. The muscles doing so are usually known as flexors (e.g., the flexor carpi radialis). Extension is the reverse of flexion and brings the two bones back to their original position at the same joints. Straightening the fingers after making a fist (extensor digitorum) or straightening the knee during walking movements (quadriceps femoris) are examples of limb extensions. Extension usually moves the trunk into the erect position (erector spinae), or the upper limb (triceps brachii, brachioradialis) or lower limb (gluteus and hamstrings) posteriorly. The terms "supination" and "pronation" refer to movements of the radius around the ulna, resulting in a standard anatomic position of the hand (supination = back of the hand lying supine, supinator), or the reverse movement by showing the palm (pronation = hand lying prone, pronator teres). In the lower limbs, ankle movements resulting in swaying of the foot are usually referred to as inward (inversion) or outward (eversion) motions (**Table 1.1**).

Table 1.1 Orientation and directional terms, body axes

	Latin(-derived) term	Meaning
Systematic arrangement	Anterior	In front of
	Posterior	Behind
	Dexter	Right side
	Sinister	Left side
	Distal	Farther from
	Proximal	Closer to
	Dorsal	Toward back
	Ventral	Toward front
	External	Toward surface
	Internal	Away from surface
	Inferior	Below
	Superior	Above
	Caudal	Toward tail
	Cranial	Toward head
	Lateral	Away from midline
	Medial	Toward midline
	Profundus	Deep
	Superficial	Nearer the surface
Motion terms	Abduction	Lateral raising
	Adduction	Lateral lowering
	Protraction	Forward motion
	Retraction	Backward motion
	Extension	Straightening
	Flexion	Bending (flexion)
	Plantar flexion	Pointing the toes (ankle flexion)
	Dorsiflexion	Lifting the foot closer to the calf (ankle extension)
	Pronation/eversion	Radius rotates over ulna, palm faces posteriorly/turns sole laterally
	Supination/inversion	Turns radius and ulna back to parallel, palm faces anteriorly (the hand is lying supine)/turns sole medially
	Rotation	Rotational motion (joint)
	Circumduction	Circular motion (arm, leg)
	Elevation	Lifting body part superiorly
	Depression	Moving body part inferiorly
	Opposition	Moving thumb to fingertips
Planes versus axes of the body	Median plane (midsagittal; Latin *sagitta*, arrow): median axis	
	Frontal (coronal) plane: frontal axis	
	Transverse plane: transverse axis	

The anatomic names of the muscles thus often contain Latin-derived terms that describe the corresponding movements, which can therefore be used to help memorize the anatomic nomenclature of the skeletal muscle system (**Tables 1.1, 1.2**).

Anatomic Terms in Skeletal Muscle

Nomenclature

- *Location.* Some muscle names refer to the location of the muscle—for example, the brachialis muscle is located in the upper arm (Latin *brachium*, upper arm). The intercostales muscles are located between the ribs (Latin *costa*, rib). The flexor digitorum superficialis (superficial = close to the surface) is located above the flexor digitorum profundus (Latin *profundus*, deep).
- *Form and shape.* Some muscles are named after their form and shape. The deltoid muscle, for example, has a triangular shape (similar to the Greek capital letter delta). The left and right portions of the trapezius muscle form a trapeze. The gracilis (from the Latin word for “thin”) at the inner thigh has a long, thin shape. The serratus anterior on the lateral thorax consists of fleshy jagged insertions on the ribs that look like a saw blade (Latin *serratus*, serrated). The platysma (from the Greek word for a flat plate) is a broad, thin muscle underneath the skin (“skinny muscle”) in the frontal neck region.
- *Size.* The gluteus maximus (Latin *maximus*, largest), gluteus medius (*medius*, medium-sized), and gluteus minimus (Latin *minimus*, smallest) refer to the various muscle sizes. The peroneus longus (long) and brevis (short) on the side of the calf are named after their lengths relative to each other.

Table 1.2 Anatomic nomenclature and definitions (selected)

Latin	English	Latin	English	Latin	English
Angulus	Angle, edge	**Fossa**	Pit (e.g., armpit)	**Planta**	Sole of foot
Apertura	Opening	**Humerus**	Arm bone	**Plexus**	Network of nerve bundles
Aponeurosis	Flattened ligament/ tendon	**Incisura**	Notch, indentation	**Processus**	Process
Ante-brachium	Forearm	**Intermedius**	Located between	**Protrusio**	Protrusion, shifting ventrally
Arcus	Arc, arch	**Interosseus**	Lying between bones (e.g., interosseus membrane)	**Radius**	Radius, spoke
Articulatio	Joint	**Inter-vertebral**	Between vertebrae (intervertebral disk)	**Retinacu-lum**	Straplike ligament
Axon	Long nerve extension propagating an impulse	**Kyphosis**	Thoracic curvature (convex) of spine	**Scapula**	Shoulder blade (pectoral girdle)
Brachium	Arm	**Labrum**	Liplike bone markings (glenoid lip of scapula)	**Scoliosis**	Lateral curvature of spine (pathologic)
Brevis	Short	**Linea**	Rimlike bone markings	**Spina**	Spikelike bony markings
Bursa	Bursa, synovial “cushion”	**Longus**	Long	**Sternum**	Breast bone
Calcaneus	Heel bone	**Lordosis**	Lumbar curvature (concave) of the spine	**Sulcus**	Furrow, groove
Capitulum	Little head (of bone)	**Lumbus**	Loin; lumbar region	**Sustentac-ulum**	Prop; bony support
Carpus, -alis	Carpals, bony crescent at the wrist	**Margo**	Margin of a bone	**Syn-arthrosis**	Articulation; slightly movable bone articulations lacking a synovial cavity
Cervical	Belonging to the neck	**Meniscus**	Semicircular supportive joint structure (fibrous cartilage)	**Synchond-rosis**	Cartilaginous joint (symphysis), with bones united by fibrous cartilage
Collum	Neck	**Malleolus**	Knuckles (ankle joint)	**Syndes-mosis**	Fastening; fibrous joints, bones united by fibrous tissue (inter-osseous membrane)
Columna	Column (vertebral column)	**Musculus**	Muscle	**Talus**	Ankle bone
Condylus	Condyle, bone surface that forms joints	**Neuron**	Nerve cell body	**Tendo**	Tendon
Costae	Ribs	**Obliquus**	Lying obliquely	**Thoracic**	Pectoral
Cristae	Comblike bony ledges	**Olecranon**	Bony process of the ulna (elbow joint)	**Thorax**	Chest
Crus, -ris	Shank	**Os**	Bone	**Trochanter**	Massive lateral process on the proximal femur
Diarthro-ses	Synovial joints (with joint cavity)	**Palma**	Inner surface of hand, palm	**Tuberculum**	Hillocklike bony mark-ings
Discus	Fibrous disklike structure (articular or intervertebral disk)	**Pars**	Part of	**Tuberositas**	Bony asperity (bony markings)
Digitus	Finger or toe (digital bones)	**Patella**	Patella (small bone at the knee joint)	**Ulna**	Ulna
Epi-condylus	Area between condyle and shaft of bone	**Pecten**	Comb; ridgelike bone markings (e.g., pec-tineal line of pubis)	**Vastus**	Large, massive
Facies	Plane area (surface)	**Perforans**	Perforating	**Venter**	Belly (of muscle)
Fascia	Connective-tissue sheath (around a muscle)	**Perforatus**	Perforated	**Vertebra**	Segment of the spinal column
Fascicle	Larger fiber bundle	**Perios-teum**	Connective-tissue ensheathment of bone		
Femur	Femoral bone, femur	**Peritenon**	Ensheathment of tendon		
Fibula	Calf bone	**Pelvis**	Pelvis		
Foramen	Hole (window)				

- *Direction of fibers.* The fibers of the rectus abdominis belly muscle (Latin *rectus*, straight) run parallel to the midline of the body (median), while the transversus abdominis and oblique muscle on the abdominal wall run at right and oblique angles to the midline, respectively.
- *Attachments.* Muscles are principally attached to bone at their origins and insertions. By convention, the origin is the less mobile attachment (Latin *origo*, source or fixed point), while the insertion is the more mobile attachment (Latin *insertio*, input or mobile point) in a normal body position. The origin is always located close to the body's midline (proximal), while the insertion is located away from the midline (distal). The origin of a muscle is always named first, followed by the insertion. For example, the brachioradialis originates from the bone of the forearm (humerus), and inserts on the radius bone more distally. By contrast, some muscles of the shoulder originate from the trunk or head and insert on the scapula (e.g., the trapezius). Muscles that move the head or trunk—for example, the erector spinae in the deep back or the sternocleidomastoid on the lateral neck—originate from lower attachment sites (caudal = from the tail) and insert on upper attachments (cranial = from the head). The muscles of the abdominal wall, the external and internal oblique, originate cranially and insert caudally. While the origin or insertion of a given muscle is always the same by anatomic convention, the fixed and mobile attachments of muscle may switch depending on body position or movements. For example, during dumbbell exercise, the brachialis and biceps brachii contract to lift the lower arm with a load (mobile attachment) closer to the humerus and shoulder (fixed attachments). During chin-ups, however, these muscles perform similarly to bring the body (now with mobile attachments) closer to the lower arm (now with fixed attachments) and bar.
- *Common attachments.* Some muscle groups originate with their overlapping tendons from common attachment sites at prominent bone structures (Latin *caput commune*, common head). Examples are the long extensors (epicondylus lateralis) and flexors (epicondylus medialis) in the forearm. Most of the adductors at the medial thigh originate from the symphysis area or around the frontal pelvic window (obturator foramen), and insert medially on a long ridge on the thigh bone known as the medial lip of the linea aspera of the femur (rough line of the femur).
- *Number of origins.* Muscles can have one or more heads at their origins (Latin *caput*, head), known as the biceps (two heads), triceps (three heads), or quadriceps (four heads). For example, the triceps of the calf has two individual heads (the lateral and medial heads) known as gastrocnemius (Greek *kneme*, calf), and one deep third head known as the soleus (Latin *solea*, sole). The term "vastus" (from the Latin word for "vast, huge") is used for powerful muscle heads such as the vastus lateralis.
- *Actions.* The primary action of a muscle is given with its name, such as flexor (flexion), extensor (extension), and adductor (drawing up) or abductor (drawing away). Examples of these are found in the anatomic names for the forearm and leg muscles (extensor digitorum, adductor hallucis, flexor digitorum), indicating the movements of the hand, foot, and digits.
- *Special descriptions.* Some names indicate special locations or functions of muscles that are related to each other. The extensor carpi radialis longus runs along the radius bone (see the radial group in the forearm muscle compartment) and acts as an extensor on the wrist (Latin *carpus*, wrist). The total length of this muscle is slightly greater than that of other wrist extensors such as the extensor carpi radialis brevis (Latin *brevis*, short), as it originates proximally from the lateral epicondyle of the forearm bone.

Note

The origin and insertion attachments of muscle are defined by anatomic nomenclature according to their more mobile or less mobile (fixed) attachment points. However, depending on performance control, the functional names for the attachments may be reversed, as in the example of the biceps and triceps forearm muscles during press-ups.

Skeletal Muscle Fiber Types

Type I and Type II Fibers

In adults, skeletal muscles are composed of a genetically determined pattern of muscle fiber types:

- Fast-twitch (oxidative-glycolytic and glycolytic) fibers, known as explosive-like power fibers (type II)
- Slow-twitch (oxidative) fibers, referred to as endurance fibers (type I)

In the embryo, early skeletal muscle dispositions are initially composed of cohorts of slow-twitch type I fibers. During development, the early type II fibers are then generated in fiber dispositions surrounding the type I fiber populations (known as cluster formation) due to the start of muscle use and its functional innervation around the time of birth. Thus, a unique distribution pattern of slow and fast fibers is generated during postnatal development, adolescence, and during adulthood in a muscle-specific way (**Fig. 1.1**). The quadriceps femoris, for example, represents a typical fast/slow mixed fiber type with an explosivelike power output (~ 60% type II versus 40% type I). As the deep part of the triceps surae, the soleus muscle represents a typically slow/fast mixed fiber type with strong postural or endurance capacity (~ 50% slow-type and 50% fast-type fibers).

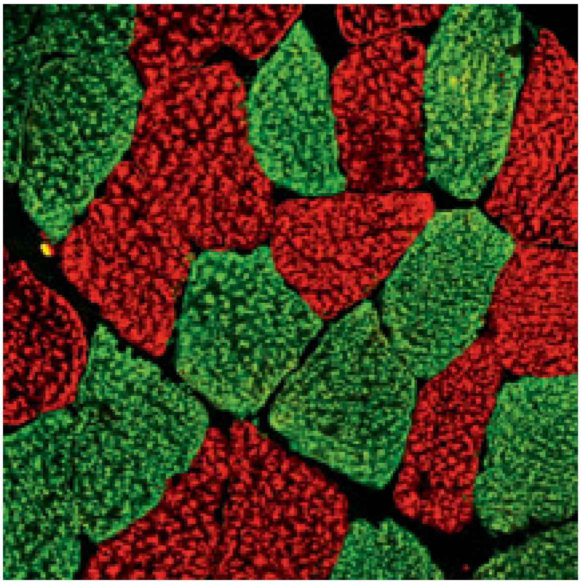

Fig. 1.1 The typical fiber distribution pattern in normal human skeletal muscle (soleus biopsy). Myosin heavy chain (MyHC) immunostaining for slow (type I, red) and fast (type II, green) MyHC in cross-sectional myofibers. Original image: M. Salanova, Charité Berlin, ZWMB, Germany.

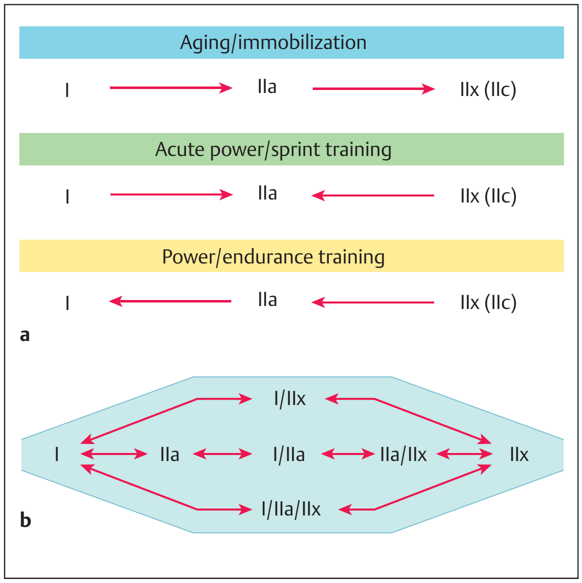

Fig. 1.2a, b Muscle plasticity (fiber switching) following exercise or disuse.

a Skeletal muscle fiber types are classified according to their myosin heavy chain (MyHC) content into: type I (endurance), type IIa (fast-switch) or type IIx/IIc (high power output, but rapidly fatigable). The arrows indicate possible fiber adaptation (plasticity) following training or immobilization, which is reflected in MyHC fiber switching of the contractile apparatus of the muscle fiber in both directions.

b Altered amounts of hybrid fibers expressing variable slow and fast MyHCs (I/IIa; IIa/IIx; I/IIx) following a training pause or in the elderly may be signs of remodeling mechanisms.

Patterns of Transition

Human skeletal muscle also contains a certain number of fast fibers as transition forms (type IIa, IIb or IIc/IIx), depending on muscle activity. However, there is an overall distribution pattern in male and female skeletal muscle that shows heterogeneity of fiber types depending on everyday lifestyle, sports, activity status in childhood, adolescence, senescence (sedentary occupations versus athletes). The pattern of fiber types in skeletal muscle may therefore not be static or irreversible, and instead follows a continuum of change throughout life (**Fig. 1.2**).

> **Note**
>
> **The fiber pattern of a muscle may not be permanently fixed, but may be significantly altered in either direction by intensive muscle training, long-duration intermittent training stops, or even by immobilization (Fig. 1.2).**

The types of skeletal muscle fibers are based on the presence of myosin heavy-chain (MyHC) proteins, which are part of the contractile myofilament apparatus (sarcomere) in variable amounts in rapidly fatigable type IIa fibers or slowly fatigable type I fibers that are continuously used during performance control (gait, stance). In addition, another fiber type, IIc/x (with a high power output but very rapidly fatigable), is found in athletes and can be transformed from undisclosed reserve fibers of the type IIa fiber pool by intensive training protocols. In a given muscle, the IIx fiber pool allows the highest power output sporadically, such as during jumping. Exhausting training protocols are likely to result in a fiber shift from type I to type IIa (in sprinters), while endurance exercises may shift the fiber pattern from type IIa to type I (in marathon and long-distance runners).

An increase in hybrid fiber formation (slow and fast MyHC expressed in one fiber, estimated at about 5–10% per muscle) is usually an indicator of intramuscular adaptation or a remodeling mechanism following intensive periods of training or after longer training intervals. Skeletal muscle plasticity may thus affect physiological functions, including endurance capacity, muscle fatigue, or power and force in a given muscle.

> **Note**
>
> **The immunohistochemical MyHC type I fiber pattern shifts from type I to type IIa or IIc fibers in the elderly or following prolonged immobilization, which may seem paradoxical. However, this should be regarded as a maladaptation of intramuscular fiber type distribution mechanisms that lacks a normal translation of sarcomeric contractile proteins into force and power, as there will be a decline rather than an increase in muscle force and power following a disuse-induced fiber switch (Snobl et al. 1998).**

Functional Muscle Compartments as a Structural Principle

From head to feet, the skeletal muscle apparatus of the human body is covered by a general fascia comparable to a whole-body stocking (cat suit). In this model, the skin—composed of hairs, sweat glands, vascular supply, and cutaneous nerves embedded in connective tissue—covers the general fascia and skeletal musculature and thus provides the final border layer between the body and the environment. However, the facial expression muscles are part of the skin layer without having a muscle fascia of their own. The actual skeletal muscles are located underneath the general body fascia (subfascially), embedded in special ensheathments such as muscle fascia and muscle compartments (**Fig. 1.3**).

The overall shapes of the typical muscle compartments in the upper and lower limbs resemble long tubes or longitudinally oriented spaces separated by fibrous connective-tissue sheets, known as septal walls or box fascia (**Fig. 1.4**). Muscle compartments contain one or more (mostly up to three) individual muscles with similar functions and are therefore termed flexor, extensor, or adductor compartments. Muscles in the same compartment usually work synergistically. Muscles from opposite compartments in the body work as antagonists, and are referred to as flexor compartments versus extensor compartments of the limbs, for example (see **Fig. 1.12,** p. 23).

Muscle compartments are classified and named according to their location in the trunk or extremities, such as the ventral and dorsal compartments of the forearm. Each compartment receives its own anatomically distinct vascular and nerve supply (afferent arteries, muscular nerves) that course via intermuscular fascicles or bundles to enter the target muscles in a given compartment. There, the nerves and arteries subdivide at the level of intramuscular connective tissue into smaller bundles that terminate in the microvascular capillary bed around smaller groups of myofibers and single fibers. The fascia of both the muscle compartment and the individual muscle belly may contain mechanosensors (mostly Pacini corpuscles), as well as pain sensors (nociceptors), which are responsible for local pain sensation and proprioceptive control (postural control) in the various motion segments of the musculoskeletal system.

Practical Tip

In this chapter, the classification of the muscle compartments is based on a functional anatomic perspective. The way in which the muscle compartments are presented can be used as a simple principle to help with general orientation, as well as for better understanding of the functional architecture of the human skeletal muscle system in sports. Understanding the general principles and more specific topographic relations between the muscle compartments and the nerve supply may be helpful in further understanding of performance control in individual body regions. It may also be helpful for finding easier ways of reaching a faster diagnosis for local muscle injuries and their possible effects on adjacent muscle groups that may result in compensatory movement patterns, in terms of protective postures.

Muscle Compartments and Their Nerve and Vascular Supply Relative to Injury Risks in Sports

For fast orientation, only those muscle compartments that may be associated with a special risk for injury in sports, for example, are described below with their individual muscle groups and their particular neurovascular supply (**Figs. 1.5** to **1.11**). Specifically, individual muscles have been selected from the muscle compartments of the trunk, forearm, pelvic girdle, and lower extremity and are listed by description, origin, insertion, action, and nerve supply in accordance with functional anatomic terminology (**Tables 1.3** to **1.11**).

Practical Tip

Following muscle injury, both muscle swelling and disruption of vascular structures in a muscle compartment may result in an acute compartment syndrome that has to be medically treated to prevent ischemia due to blood congestion. Otherwise, there will be a risk of more severe tissue damage—as typically seen, for example, in the anterior compartment of the lower leg. The treatment may thus include skin incision and transection of the affected muscle fascia (fasciotomy) as an acute method of relieving congestion pressure. A chronic compartment syndrome may occur in extensively trained athletes, for example. This symptom is associated with pain during exercise due to microtears in fibers and swelling, which increases intracompartmental pressure, while pain is usually relieved when the exercise is completed.

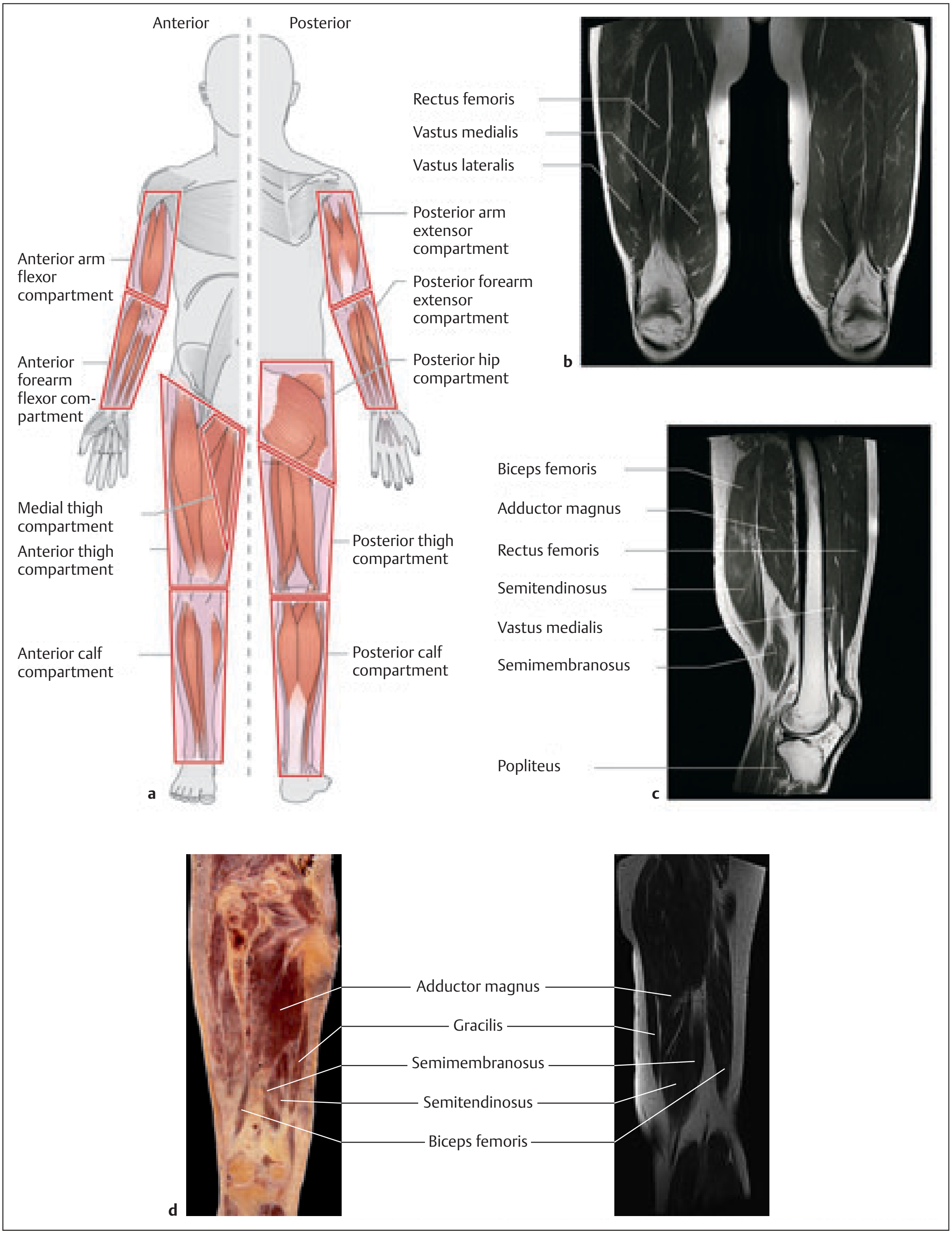

Fig. 1.3a–d Skeletal muscle compartments in the human body and magnetic resonance images (MRIs) of the thigh muscle compartments (examples).

a View from anterior (left) and from posterior (right), showing the anatomic location of the individual muscle compartments that are most relevant to sports injuries (for the intrinsic trunk muscles, see **Tables 1.3** and **1.4**).

b MRI. The anterior thigh muscle compartment (coronal view). 1, vastus lateralis; 2, rectus femoris; 3, vastus medialis.

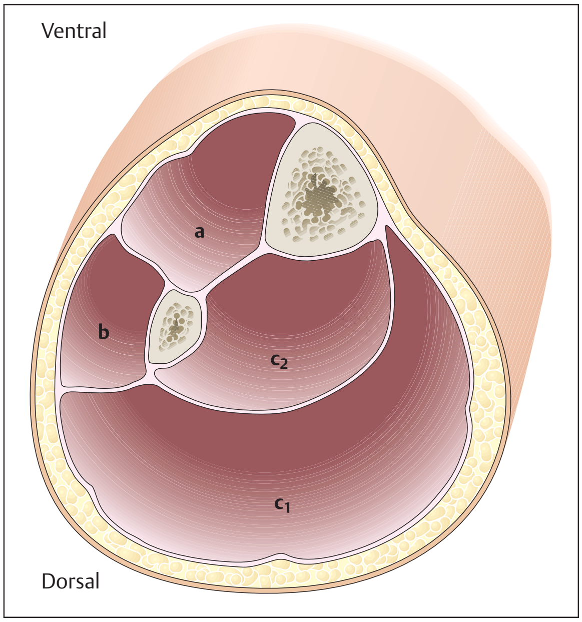

Fig. 1.4 Cross-sectional view through the calf, with “empty” muscle compartments. a, extensor calf muscle compartment; b, lateral calf muscle compartment (peroneus compartment); c_1, superficial flexor calf muscle compartment; c_2, deep flexor calf muscle compartment.

Trunk Muscles

Abdominal Wall Muscles

The sheetlike abdominal muscles (**Fig. 1.5** and **Table 1.3**), external oblique, internal oblique, transversus abdominis, and rectus abdominis span the lower thoracic cage to the pelvic girdle and compress the abdominal wall during heavy lifting. They receive their nerve supply via intercostal nerves (T7–T12) as well as from the iliocostal and ilioinguinal nerves coursing freely between the broad flat muscle sheets. The intercostal or subcostal arteries run in parallel to the abdominal wall and provide the blood supply.

The rectangular, fleshy quadratus lumborum in the deep lumbar region (**Fig. 1.5**) is supplied by the subcostal nerve (an extra intercostal nerve that has no intercostal space) and subcostal artery.

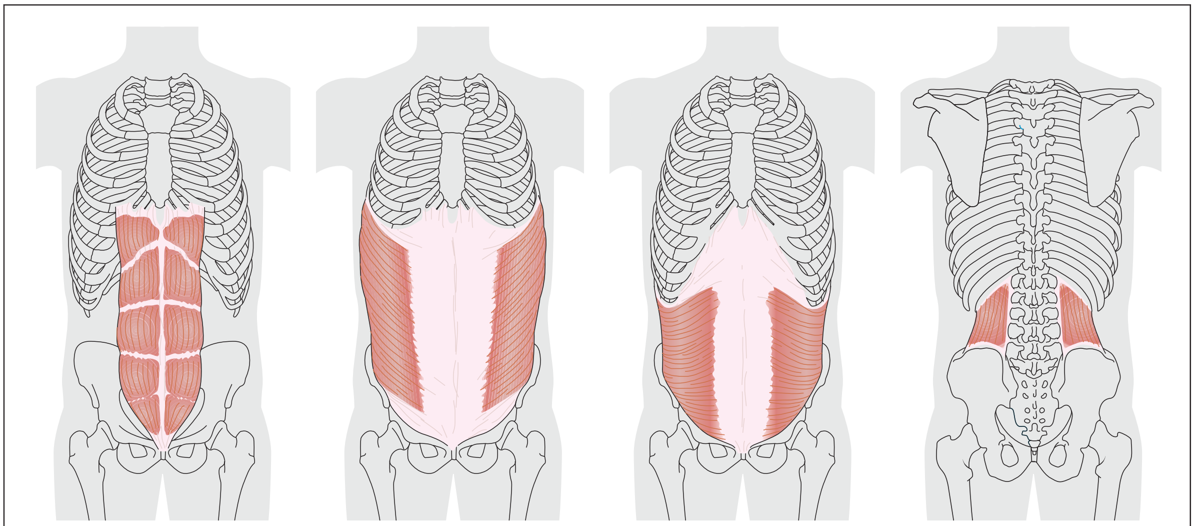

Fig. 1.5 Abdominal wall muscle compartments (the transversus abdominis not shown; see **Table 1.3**).

Fig. 1.3a–d *continued*

c MRI. The anterior and posterior thigh muscle compartments (sagittal view). 1, adductor magnus; 2, semitendinosus; 3, semimembranosus; 4, biceps femoris; 5, popliteus; 6, rectus femoris; 7, vastus medialis.

d Anatomic dissection in comparison with MRI of the medial thigh muscle compartment (coronal views). *Left panel:* An anatomically dissected thigh from a 73-year-old man, showing a coronal view of the medial thigh muscles. The connective-tissue invasion (intramuscular and intermuscular adipose tissue) and slight reduction in muscle size due to aging should be noted. (Dissection and image courtesy of F. Glöckner and E. Heuckendorf, Department of Anatomy, Charité Berlin, Germany.) *Right panel:* An MRI image from a healthy 32-year-old man with well-trained medial thigh muscles using coronal view comparable to dissected thigh in the left panel. (MRI images in **Fig. 1.3b–d** courtesy of D. Belavý, Center for Bone and Muscle Research, Charité Berlin, Germany.)

Table 1.3 Abdominal wall muscle compartment—major actions: lumbar flexors, lateral flexors, lumbar rotators, and breathing assistance

	Muscle	Description (palpation)	Origin (O), insertion (I)	Innervation (segments)	Action
Lumbar flexors	Rectus abdominis *(rectus,* straight) Pyramidalis	Medial pair of flat muscles ensheathed by aponeurosis (rectus sheath) from lateral muscles; extends from ribs to pelvis, segmented by three tendinous intersections	O: Costal cartilages of ribs 5–7 I: Pubic crest and symphysis	Intercostal nerves T5–T12	• Flexes and rotates lumbar region • Stabilizes pelvis • Works against intra-abdominal pressure • Assists in forced expiration
Lateral flexors	External oblique	Most superficial flat muscle of abdominal wall, with fibers running downward obliquely from lateral to medial (like hands in pants pockets!)	O: Outer surfaces of ribs 5–12 I: Lateral aponeurosis of rectus sheath (outer sheet)	Intercostal nerves T5–T12 Iliohypogastric nerve	As for rectus abdominis • Lateral flexion (ipsilaterally) • Rotates trunk contralaterally
	Internal oblique	Flat middle muscle of abdominal wall, with fibers running obliquely from medial to lateral (opposite to external oblique)	O: Lumbar fascia (deep), iliac crest, inguinal ligament I: Costal margin, rectus sheath	Intercostal nerves T8–T12 Iliohypogastric and ilioinguinal nerves	As for external oblique • Rotates trunk ipsilaterally
	Transversus abdominis	Innermost flat muscle of abdominal wall, with horizontal fibers	O: Lumbar fascia (deep), iliac crest, anterior superior iliac spine (ASIS) I: Rectus sheath (inner sheet)	As internal oblique, plus genitofemoral nerve	• Abdominal pressure bilaterally • Rotation (ipsilateral)
Lumbar rotators	Quadratus lumborum	Fleshy deep muscle forming part of posterior abdominal wall	O: Iliac crest I: Costae 12 + transverse processes of lumbar vertebrae 1–4	12th intercostal nerve Subcostal nerve and upper lumbar nerves (ventral rami)	• Abdominal pressure bilaterally • Lateral flexion unilaterally • Assists in forced inspiration

Muscles of the Vertebral Column

The local intrinsic back muscles, known as the erector spinae (**Fig. 1.6** and **Table 1.4**) span the pelvis, vertebral column, and dorsal thoracic cage structures (ribs). The erector spinae is subdivided into three large columns located lateral to the vertebral column (lateral tract, straight system) and in the deeper back as a set of shorter columns medial to the vertebral column (medial tract, oblique system). The neck muscles are formed by a continuation of the two columns from the back to the head (e.g., the semispinalis and longissimus group). The intrinsic muscle groups are covered by a large fascia known as the thoracolumbar fascia, which runs from the pelvis to the head. The erector spinae is mostly covered by superficial muscles, the broad and flat latissimus dorsi and trapezius, the spinocostalis group, superior and inferior serratus, and the scapulospinal group of rhomboid muscles.

The erector spinae receives its nerve supply via the dorsal rami of the spinal nerves from each of the spinal cord segments, which thus penetrate the muscle in a segmental pattern. The deep neck muscles, rectus capitis and obliquus capitis, are innervated by the first dorsal ramus of spinal nerve C1, known as the suboccipital nerve. The intrinsic back muscles are supplied by dorsal rami of the intercostal arteries, and the deep neck muscles by the occipital artery.

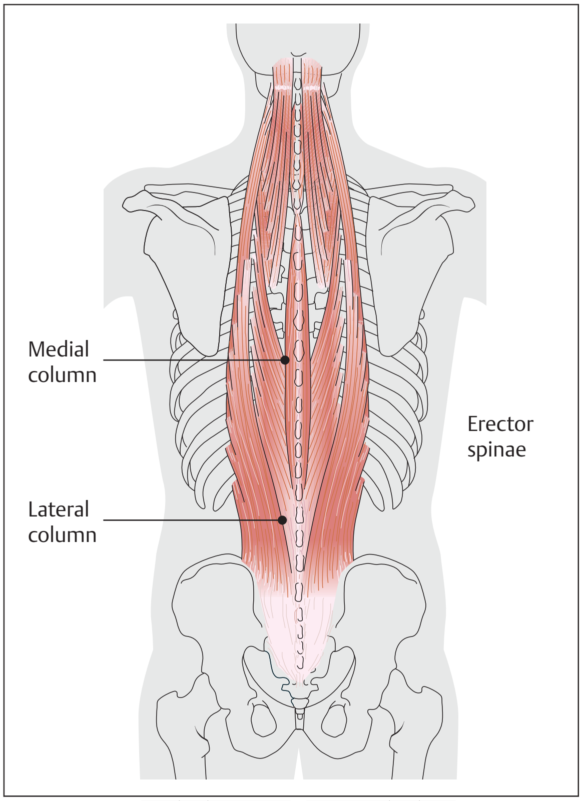

Fig. 1.6 Posterior trunk muscle compartment. The erector spinae, with lateral and medial columns (intrinsic back muscles).

Muscles of the Anterior and Posterior Arm Compartments

The anterior arm muscle compartment spans the shoulder, elbow joints, wrist, and finger joints (arm flexor compartment, **Fig. 1.7a** and **Table 1.5**.) and is supplied by the musculocutaneous nerve (humerus) or the medial and ulnar nerve (forearm). The posterior brachium and forearm muscle compartment (arm extensor compartment, **Fig. 1.7b** and **Table 1.5**) is supplied by the radial nerve. All of the arm muscle compartments are supplied by the subclavian artery (major afferent artery), brachial artery and

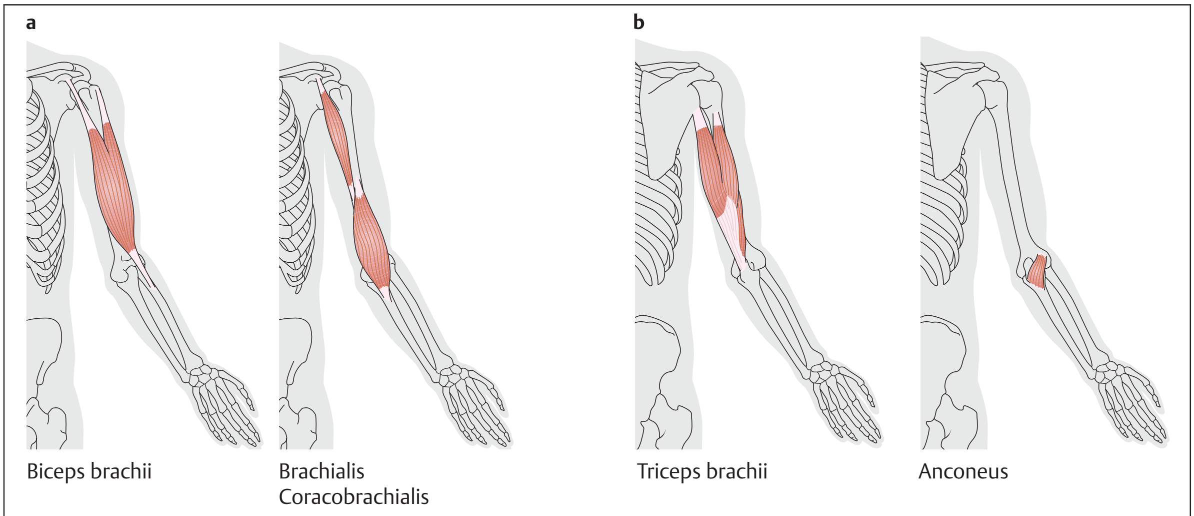

Fig. 1.7a, b Arm flexor and extensor muscle compartments.
a Arm flexor compartment (anterior view). **b** Arm extensor compartment (posterior view).