# Mechanical properties of muscle tissue

## Characteristics of muscles and their mechanical properties

### The structure of skeletal muscle

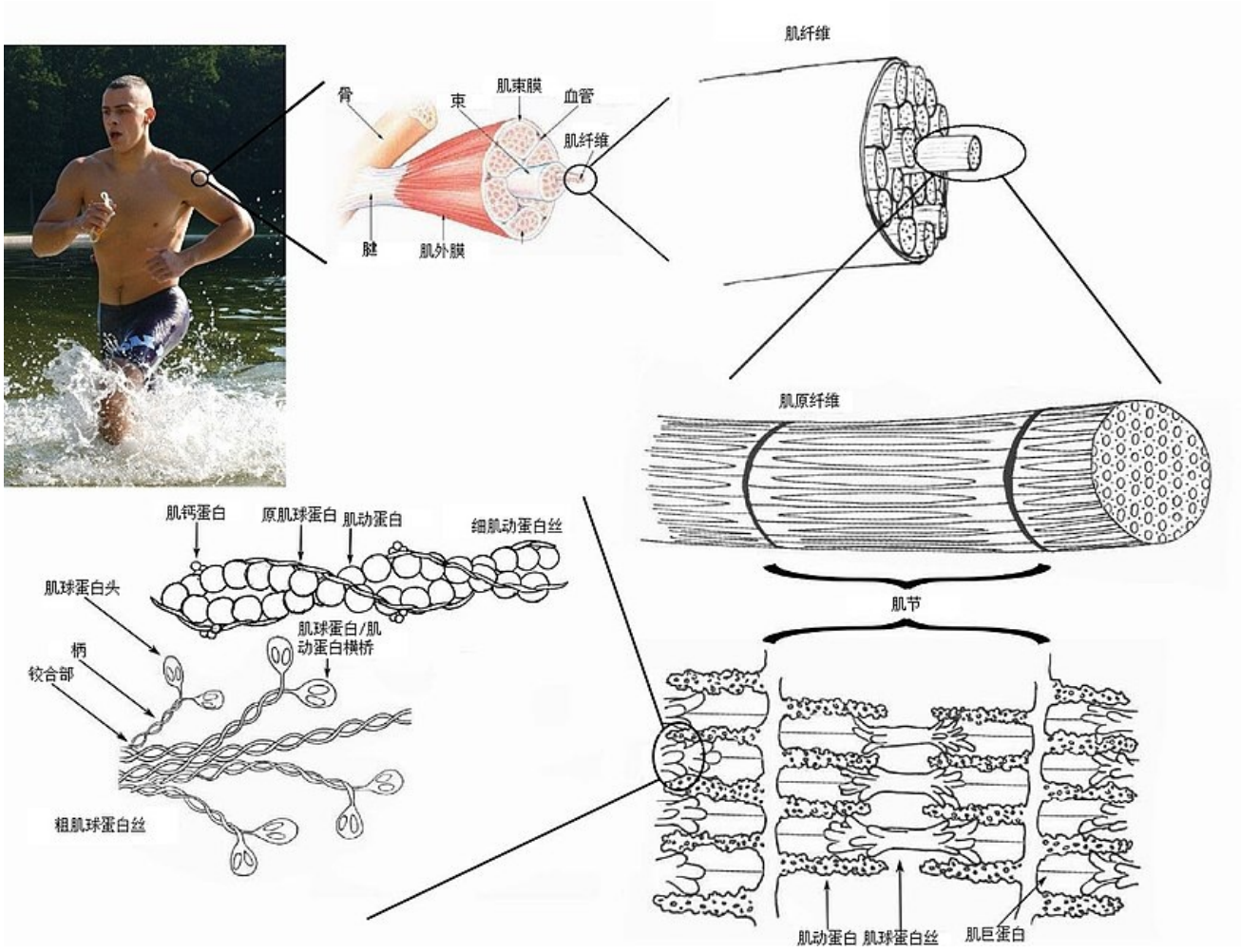
The basic active component of the muscle are striated muscle fibers.

They are the basis of the moving component of the locomotor system. The functional and biomechanical unit of muscle are motor units – groups of muscle fibers that are innervated by one motoneuron.

A muscle fiber is a complex multinucleated cell, 40-100 micrometers thick and with some exceptions, 1-40 millimeters long. Each muscle fiber is separated from the surroundings by a cell membrane — the sarcolemma, which surrounds the cytoplasm — the sarcoplasm. Sarcomeres are the intrinsic contractile unit of muscle fibers .

The structure of the sarcomere itself is made up of parallel myofilaments — actin (4 nm in diameter) and myosin (10 nm in diameter), which either partially or completely overlap depending on the degree of muscle contraction. Thanks to this unique arrangement of both proteins , a typical microscopic image of striated muscle is created , where isotropic (light) and anisotropic (dark) stripes alternate. The isotropic strip is the part of the sarcomere where the filaments of the contractile protein actin do not overlap with the myosin filaments. The anisotropic band forms the darker part of the sarcomere where myosin filaments are located (including the section where myosin overlaps with actin).

The flexibility of the sarcomere is primarily determined by the proteins titin and nebulin.




Muscles are connected to the main structure of the body, the skeleton, by means of tendons , composed of tough fibrous tissue. Tendons have considerable strength: they can support a weight of 6-10 kg per 1 mm 2 cross-section.

Some muscles (e.g. facial muscles) are attached to the skin, other types to joint capsules .

Tendons are bundles of collagen fibers arranged parallel or helically. Muscle fibers and tendon fibers slide into each other in a step-like fashion. During contraction, the tension of the muscle fibers is transferred gradually to the muscle fiber , then to the tendon fiber, and then to the tendon fibers themselves. This sequence ensures great mechanical strength.

They are attached to the skeleton in a rope-like manner or flat. The tensile engagement of the contracting muscle is soft and flexible.

The main function of muscles is to change the energy of chemical bonds into mechanical work. This change is carried out by the muscles with a characteristic movement — contraction. Contraction occurs on the basis of impulses from motor nerve fibers.

## Mechanical properties of muscles

Types of muscle contraction: Deformation (change in position or shape) of physical objects in space and time is defined as movement. The movement of living objects is subject not only to the laws of mathematics and physics like inanimate objects, but living objects are also capable of intentional movement, which is one of the basic manifestations of life.

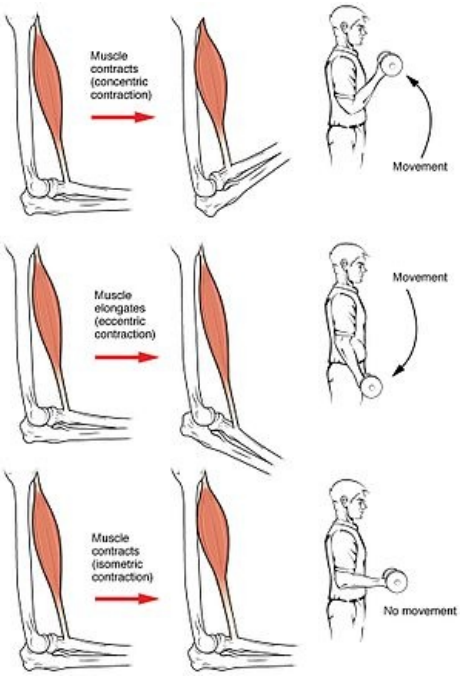
Four properties of  muscle tissue are the key for each movement :

- excitability: reception of stimuli and subsequent response
- contractility: generation of force and movement by shortening of muscle
- extensibility: the ability of muscle tissue to be stretched — lengthened
- elasticity : tissue is able to return to the original state in which it was before contraction or extension

In addition to the active organs (muscles) performing the movement, connective tissue (i.e. fibrous, cartilage and bone tissue) also participates in this process

We distinguish two basic functions of skeletal muscles

- **Kinetic function** — during movement, only the currently moving, relaxed muscles have. for example, only the rectus femoris muscle extends the knee.
- On the other hand, muscles that are stabilized and fixed have a **fixation function during movement**. These muscles serve to optimize movement. for example, vastus medialis and lateralis fix the extended knee .




The movement properties of muscles depend on the internal structure of the muscle. According to it, the main mechanical components of the movement change: the height of the lift and the force with which the movement is performed.

During contraction, the muscle shortens by 30-40% of its length. A muscle that is not affected by a deforming force is at its so-called resting length.

The speed of muscle contraction ranges from 25-75 milliseconds and depends on the type of muscle fiber .

**Mechanical components of the movement:** the height of the lift and the force with which the movement is performed depends on the internal structure of the muscles.

Muscles with parallel longitudinal fibers have a greater length of stroke but less force than muscles with oblique bundles (pinnate muscles) for the same shortening.

In a muscle with pinnate bundles, a greater number of short muscle fibers are involved in the same size abdomen . A muscle can be shortened by a third, sometimes up to half, of the length of its muscle bundles. If a muscle with a longitudinal adjustment of the bundles is contracted by a third, it has a greater lift height, but less force. If a muscle with feathered bundles contracts by a third, it has a small height of stroke, but a large force.

Muscles with longitudinal bundles are therefore usually clamped further from the axis of the joint (on the surface), muscles with feathering closer to the axis of the joint (in depth), because a large force must be applied on a small path of movement. The area that corresponds to the sum of the cross-sections of all muscle fibers , i.e. .**the physiological cross-section of the muscle** (FP) , is directly proportional to the force of contraction of the whole muscle.

From the point of view of biomechanics , muscle strength depends primarily on:

- The number of muscle fibers — the more fibers a muscle contains, the more force it can produce.
- Length — the longer the muscle, the more force it can usually produce.
- Number of activated motor units
- Action of the elastic component of muscle and tendon.

## Properties of passive and active muscle

"An active muscle is characterized by higher stiffness than a passive muscle. The stiffness of the muscle increases with the degree of excitation. The increase in force that the muscle is able to transmit through active contraction is dependent on the extent of the actual stretching of the muscle . The muscle's ability to exert an active force during

load transfer depends on the degree of insertion  the actomyosin complex , i.e. on the length of the sarcomere .it is defined according to the maximum of the Gordon curve - see Isometric contraction ).

### Electromyography

Examination of muscle activity, Electromyography (EMG), is a diagnostic method recording electrical voltage changes (so-called electrical potentials) of muscles. Writes a time recording of skeletal muscle contractions. For the actual measurement, injection electrodes are used, which sense the electrical activity of certain motor units . (More here Electromyography )

Electromyography examination

## Mechanical loading of muscles and its effects

Repeated intensive activity of the locomotor apparatus results in changes in its structure to varying extents. Physical stress causes functional muscle hypertrophy (growth of muscle tissue), often accompanied by a partial change in the histo-chemical composition of the fibers. Targeted isometric contraction can achieve plastic modeling of the muscles (we can notice it especially in athletes). Lack of movement, hypokinesis, on the contrary leads to hypotonia up to muscle atrophy .

Mechanical loads can be divided into individual groups according to the length of the muscle contraction , the force that is developed during the load, and the involvement of certain functional muscle groups:

- Strong
- Strength-endurance
- Skillful
- Endurance
- Strength-endurance

A number of other mechanical factors affect the muscular apparatus. We distinguish between **static** stimuli (the acting stimulus and the object of action are mutually at rest) and **dynamic** (in the case of a moving object of action). Most mechanical factors have both a negative and a positive effect of action. We positively use mechanical energy in treatment and therapy.

### Effects of mechanical forces

#### Gravity

Gravitational force is constantly acting between the Earth and man. If the gravitational acceleration "g" increases, we are talking about the so-called overloading of the organism. We distinguish between positive and negative overload . With a positive overload, the force is directed from the head to the feet, with a negative one, the opposite. In a situation where centripetal and centrifugal forces are equal and act in the opposite direction, the so-called weightless state occurs. In this, gravitational irritation, neuromuscular coordination decreases, muscle tone decreases, and there is a disorder in the analysis of the position in space.

#### Vacuum

We use the reduction of atmospheric pressure therapeutically in so-called negative pressure chambers , in which the pressure is reduced by 20-40 kPa. These chambers have a positive effect on respiratory diseases. An exponential decrease in atmospheric pressure occurs with increasing altitude.

#### Overpressure

We use the overpressure of atmospheric pressure in so-called overpressure chambers . The excess pressure in them varies between 26-54 kPa and they are suitable for the treatment of certain lung diseases, poisoning, burns and severe shock states. As a result of overpressure, decompression syndrome can occur — caisson disease .

### Effects of mechanical energy

The effect of mechanical energy is given by the impulse of the force of interaction between two bodies. We refer to a negative effect on the human body as a mechanical injury. It can be caused by impact, a sudden change in movement, or long-term exposure to pressure. The type of injury depends on:

- Magnitudes of force impulse
- The direction of the acting impulse
- The size of the area on which the force acts

We use the positive effects of mechanical energy in therapeutic methods and procedures. We distinguish:

- Therapeutic physical exercise — increasing physical fitness
- Ergotherapy — increasing muscle tone and the range of mobility at work
- Mechanotherapy — various types of massage

# Muscle division

## Division of muscles according to their action

Joints are surrounded by different groups of muscles . Their different locations then act on the lever systems in different directions.

- Agonists are muscles that act and initiate movement in one direction.
- Antagonists are muscles creating an opposing movement.
- Synergists are muscles used when performing a certain type of movement.

The interplay of agonists and antagonists is important for stabilizing the movement itself. The action of opposing muscle groups stabilizes a certain position of the body and its segments. An example of this interplay are the muscles of the abdominal wall , which stabilize the upright position in this way ( postural muscles ).

## Division of muscles from a functional point of view

### According to the importance of involvement in movements

- **Main function** : e.g. biceps brachii flexes the forearm.
- **Secondary function** : e.g. the biceps brachii muscle supinates the forearm.
- **The muscles have a neutralizing function** , which cancel the inappropriate direction of movement caused by the main and secondary muscles.

## Division of muscles according to their relationship to joints

- **Uniarticular muscle**s relate to only one joint over which they pass.
- **Multi-joint muscles** pass over multiple joints and have different relationships to them.

# Types of muscle contraction

The basis of muscle function is contraction — muscle contraction. According to the external manifestations of muscle contraction, several basic types of contraction are distinguished:

- **An isotonic contraction** is a contraction in which the length of the muscle changes and the internal tension of the muscle remains the same.
  - **A concentric contraction** is a contraction in which the muscle shortens . It is characterized by an increase in the volume of the muscle belly and an actual shortening of the muscle. In this type of shortening, the muscle does work and the muscle force acts in the same direction as the moving body segment. The result of concentric muscle contraction is not only movement performed at a constant speed, but also acceleration, acceleration of movement. The molecular essence of concentric contraction is expressed by the classical model of contraction — the theory of bridges.
  - **An eccentric contraction** is a contraction that lengthens the muscle. Muscle attachments move apart during this type of contraction. The result is movement, but mostly braking, decelerating movement.
- **An isometric contraction** is a contraction during which the muscle is activated but no movement is generated. During isometric contraction, the length of the muscle remains constant — the distance between the beginning and the attachment of the muscle does not change. However, the activity of the muscle is evident in the change in muscle tension.

# Links

## Related Articles

- Muscle
- Biomechanics of muscle contraction
- Connection of excitation and contraction
- Mechanical properties of tissues — Support and movement system

## References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