Mechanical characteristics of muscles

Characteristics of muscles and their mechanical properties

Skeletal muscle structure

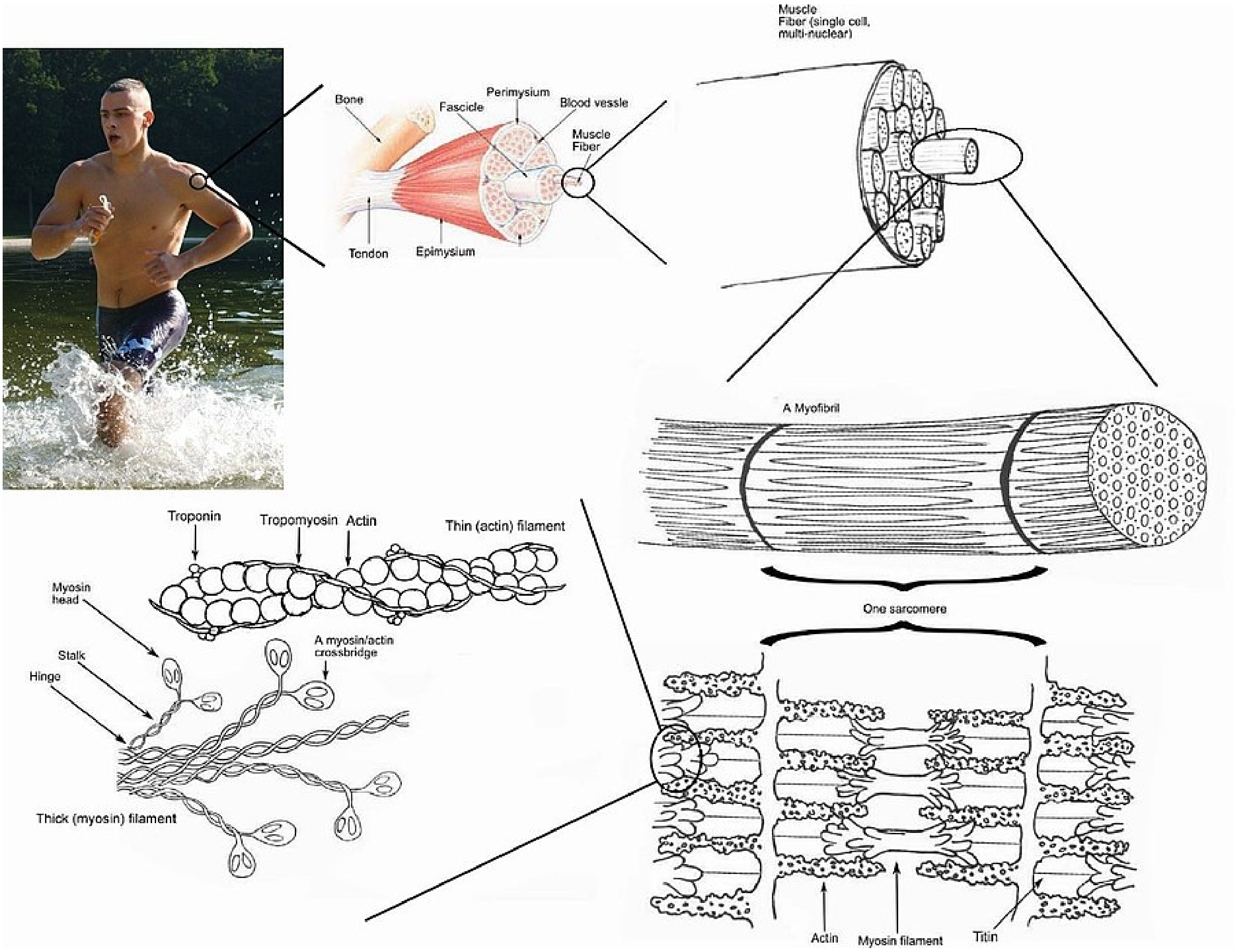
The basic active component of muscle is striated muscle fibers.

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

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 — sarcolemma, which surrounds cytoplasm — sarcoplasm. Sarcomeres are the intrinsic contractile unit of muscle fibers.

The structure of the sarcomere itself is made up of parallel myofilaments — actin (4nm in diameter) and myosin (10nm in diameter), which either partially or completely overlap depending on the degree of muscle contraction. Thanks to this unique arrangement of both protein thus creates a typical microscopic image of striated muscle, where isotropic (light) and anisotropic (dark) stripes alternate. The isotropic strip is the part of the sarcomere where the contractile protein actin filaments 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 elasticity of sarcomeres is primarily determined by the proteins titin and nebulin.



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

Some muscles (eg mimic) are attached to the skin, other types to joint sockets.

Tendons are bundles collagen fibers arranged parallel or helically. Fibers muscle a tendon fibers slide into each other in a step-like manner. The muscle fiber pull is at contraction transmitted successively to muscle fiber, then to tendon fiber a then onto the tendon's own fibers. This sequence provides a large mechanical strength.

They attach to the skeleton stringy or flat. The tensile engagement of a contracting muscle is soft and flexible.

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

Mechanical properties of muscles

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

There are four key to each move properties muscle tissues:

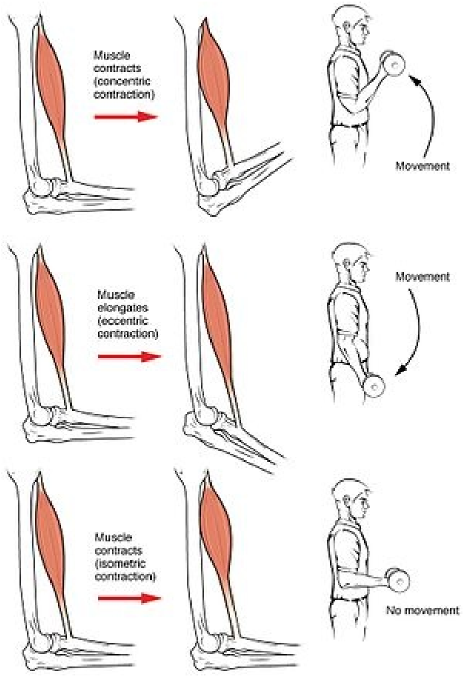
- excitability: reception of stimuli and subsequent response
- contractility: the generation of force and movement by shortening muscle tissue
- extensibility: the ability of muscle tissue to be stretched — lengthened
- elasticity: tissue is able to return to the original state in which it was before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

In addition to active organs (muscles) performing movement, connective tissues (i.e. fibrous, cartilaginous and bone tissue) are also involved in this process

We distinguish two basic functions of skeletal muscles

- **Kinetic function**— only the currently moving, relaxed muscles have during the movement.

E.g. only m. rectus femoris extends the knee.



Types of muscle contraction

- On the other hand, muscles that are stabilized and fixed during movement have the **function of fixation**. These muscles serve to optimize movement.

E.g. m. 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.

The muscle at contraction shortens by 30-40% of its length. A muscle that is not affected by a deforming force, is in the 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 stroke and the force with which the movement is performed depends on the internal muscle structure.

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

In a muscle with pinnate bundles, a greater number of short muscle fibers are involved in the same size belly. A muscle can be shortened by a third, sometimes up to half, of the length of its muscle bundles. If a third of the contracts it uses a muscle with a longitudinal adjustment of the bundles, has a greater height of stroke, but less power. 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 generally clamped further from the joint axis (on the surface), striated muscles closer to the joint axis (in depth), because a large force must be exerted over a small range of motion .The area corresponding 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 entire muscle.

In terms 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 degree of actual stretching of the muscle. The ability of a muscle to exert an active force during load transfer depends on the degree of insertion of the actomyosin complex, i.e. on the length of the sarcomere."[1] Unstimulated skeletal muscle can be stretched approximately up to 45% (cardiac about 25%) of its resting length (100% resting length is defined according to the maximum Gordon's curve - see Isometric contraction).

Electromyography

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

Examination of muscle activity

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 induces functional muscle hypertrophy (muscle tissue growth), often accompanied by a partial change in the histo-chemical component 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 other hand leads hypotonia to atrophy of the muscles.

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

- Strong
- Strength-endurance
- Dexterous
- 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 force 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 — caisson disease can occur.

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 pulse
- Direction 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 — increase in muscle tone and range of motion by work
- Mechanotherapy — various types of massage

Muscle division

Division of muscles according to their action

Jointss 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 the 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 the stabilization of the movement itself. The action of opposing muscle groups stabilizes a certain position of the body and its segments. An example of this interaction is 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. m. biceps brachii flexes the forearm.
- **Secondary function**: e.g. m. biceps brachii supinates the forearm.
- **Neutralizing function** then have muscles that cancel the inappropriate direction of movement caused by the main and secondary muscles.

Division of muscles according to their relation to joints

- **Uniarticular muscles** relate to only one joint over which they pass.
- **Multijoint 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:

- A **Isotonic contraction** is a contraction in which the length of the muscle changes while the internal tension of the muscle remains the same.
  - A **Concentric Contraction** is a contraction that shortens the Muscle. 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 contraction of the muscle is not only a movement performed at a constant speed, but also an acceleration, an acceleration of the 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 in which the muscle is lengthened. 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
- Coupling of excitation and contraction
- Mechanical properties of tissues — Support and movement system

References

1. * COMPENDIUM,. *Mechanical properties of skeletal muscle* [online]. [cit. 2013-01-

09]. <http://biomech.ftvs.cuni.cz/pbpk/kompendium/biomechanika/vlastnosti_komplex_sval.php>.

References

- NAVRÁTIL, Leoš and Jozef Rosina, et al. *Medical Biophysics.* 1. edition. Prague: Manus, 2001. 357 pp. ISBN 80-902318-5-3
- NAVRÁTIL, Leoš and Jozef ROSINA, et al. *Medical Biophysics.* 1. edition. Prague: Grada, 2005. 524 pp. ISBN 80-247-1152-4.
- COMPENDIUM,. *Mechanical properties of skeletal muscle* [online]. [cit. 2013-01-09]. <http://biomech.ftvs.cuni.cz/pbpk/kompendium/biomechanika/vlastnosti_komplex_sval.php>.

- ŠIHÁK, Radomír – GRIM, Miloš. *Anatomy.* 3. edition. Grada, 2011. ISBN 978-80-247-3817-8.