name number study group

Theoretical part

Recruitment and summation in skeletal muscle

Myography and electromyography

Myography is a method for recording skeletal muscle contractions. On the contrary, electromyography (EMG) is a method registering the electric activity produced by skeletal muscle.

Muscle fibre

Each individual skeletal muscle cell (or myocyte or fiber) contains a dense parallel array of smaller, cylindrical elements called myofibrils that have the diameter of a Z disk (Figure 1). Each of these myofibrils comprises repeating units, or sarcomeres, that consist of smaller interdigitating filaments called myofilaments. These myofilaments come in two types, thick filaments composed primarily of myosin and thin filaments composed primarily of actin. The sarcomere extends from one Z disk to another. Sarcomeres stacked end to end make up a myofibril. The repeating sarcomeres are most highly organized within skeletal and cardiac muscle and impart a striped appearance.

Thin filaments are 5 to 8 nm in diameter and, in striated muscle, 1 μm in length. In striated muscle, the thin filaments are tethered together at one end, where they project from a dense disk known as the Z disk. The Z disk is oriented perpendicular to the axis of the muscle fibre; thin filaments project from both its faces. Not only do Z disks tether the thin filaments of a single myofibril together, but connections between the Z disks also tether each myofibril to its neighbours. These interconnections align the sarcomeres and give skeletal and, to a lesser extent, cardiac muscle its striated appearance.

The thick filaments are 10 nm in diameter and, in striated muscle, 1.6 μm in length. They lie between and partially interdigitate with the thin filaments. This partial interdigitation results in alternating light and dark bands along the axis of the myofibril. The light bands, which represent regions of the thin filament that do not lie alongside thick filaments, are known as I bands because they are isotropic to polarized light. The Z disk is visible as a dark perpendicular line at the centre of the I band. The dark bands, which represent the myosin filaments, are known as A bands because they are anisotropic to polarized light. During contraction, the A bands are unchanged in length whereas the I bands shorten. Within the A bands, the pivoting heads of the thick myosin filaments, the molecular motors, establish cross-bridges to the thin actin filaments. As will be discussed later, the adenosine triphosphate (ATP)-dependent cycle of making and breaking cross-bridges causes the actin filament to be drawn over the myosin filament and thereby results in muscle contraction.

Thin filaments consist of actin, tropomyosin, and troponin. The role of tropomyosin is to interfere with the binding of myosin to actin. Troponin is a heterotrimer consisting of troponin T (which binds to a single molecule of tropomyosin), troponin C (which binds Ca^{2+}), and troponin I (which binds to actin and inhibits contraction). The coordinated interaction between troponin, tropomyosin, and actin allows actin-myosin interactions to be regulated by changes in concentration of Ca^{2+}.

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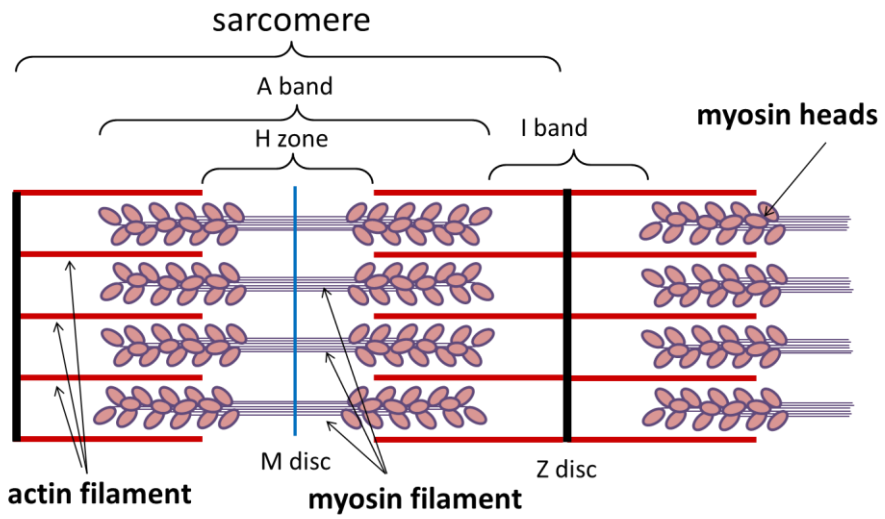

Figure 1: Morphology of the skeletal muscle fibre

Types of muscle fibres:

- **S (slow)** – slowly get tired, used in long-term performance, many mitochondrias, well vascularized, a lot of myoglobin
- **F (fast)** – fast contraction, quickly get tired, a lot of glycogen, little myoglobin

1 Excitation – contraction of skeletal muscle

The electric activity of skeletal muscle

Skeletal muscle is innervated by alpha motor neurons located within the anterior horn of the spinal cord. An action potential spreading along the efferent axons covered by the myelin sheath from the spinal cord towards the motor end plates induces opening of the voltage-gated calcium channels located within the axon terminals. This current causes the calcium concentration to rise and consequently causes acetylcholine to leak into the junctional cleft.

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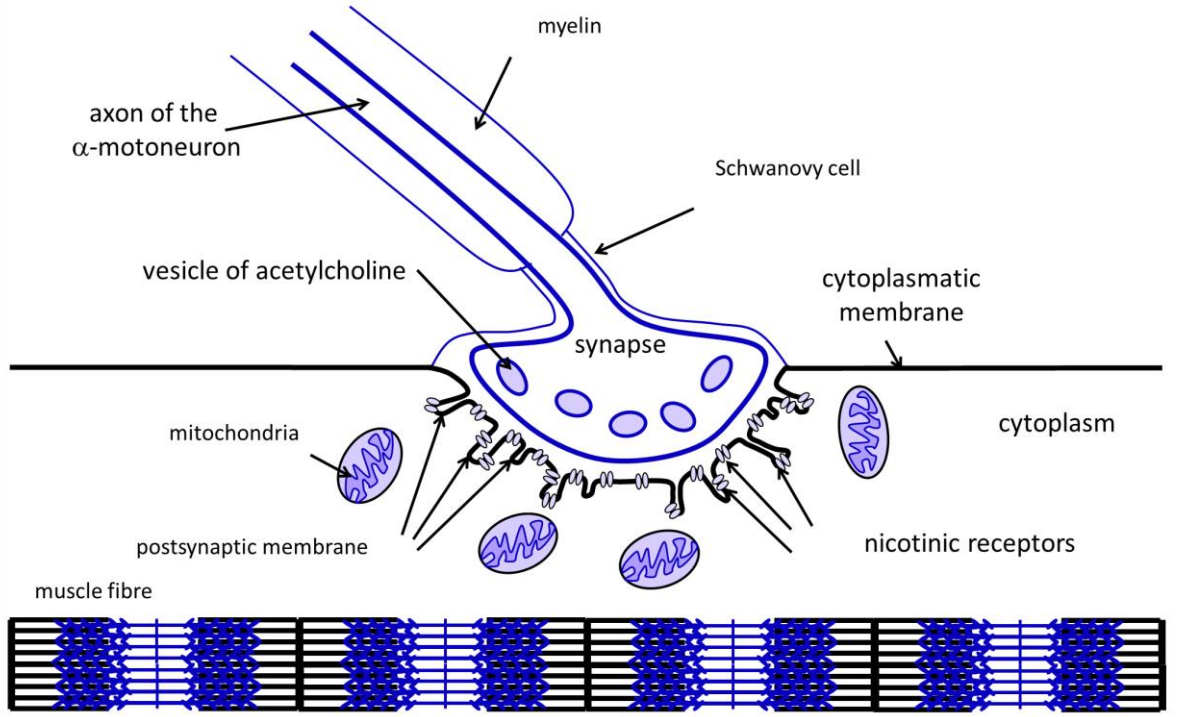

Figure 2: Motor end-plate

Acetylcholine diffuses towards the postsynaptic membrane and binds to the M-type of the acetylcholine receptor and thus opens the ligand-gated sodium channels (Figure 2). Sodium leaks into the muscle cell and this sodium current shifts the resting potential and produces a local depolarisation. If the local depolarisation overshoots the threshold, the action potential is produced. It spreads across the sarcoplasmic membrane (the cytoplasmic membrane of muscle) including the T-tubules representing intracytoplasmic invagination of the membrane. Within the T-tubule there are DHPR (dihydropyridine receptors) activable by a voltage change tightly linked with RyR 1 (ryanodine) receptors embedded on the sarcoplasmic reticulum.

The sarcoplasmic reticulum is a specialized cytoplasmic reticulum capable of storing, releasing and sucking up a large amount of calcium ions. Its terminal cisternae are enclosed to the T-tubule creating a complex known as a triad (3). One triad consists of a single T-tubule surrounded by two terminal cisternae. The RyR 1 receptors activated by the voltage change transmitted by DHPR release the sarcoplasmic calcium load into the cytoplasm and its concentration soars, which triggers muscle contraction.

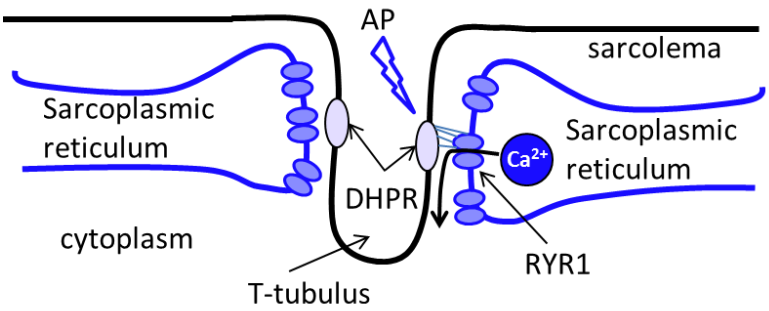

Figure 3: Complex of a T-tubule and two sarcoplasmic reticuli

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Muscle contraction

Muscle contraction is based on the reversible cross-bridges formation and the reciprocal shift of the contractile proteins, actin and myosin, which are organized as thin and thick myofilaments. This interaction is modulated by the troponin-tropomyosin complex.
Thin myofilaments are composed of actin. Each strand of actin filament is associated with tropomyosin and a troponin complex, which also directly interacts with actin. Each thin myofilament strand may be considered as a series of regulation units. Cardiac troponin is a heterotrimer consisting of troponin C (a receptor binding Ca2+), troponin I (a protein inhibiting interaction between actin and myosin), and troponin T (a subunit anchoring troponin I and C to tropomyosin). Binding Ca2+ to troponin C triggers a conformational change in the troponin-tropomyosin complex and unfolds the myosin binding side on actin.
Myosin represents the fundamental structural unit of a thick myofilament. Each myosin molecule contains two heavy chains and four light chains. A heavy chain constitutes a myosin axial structure stretching out as globular "head" regions. On each "head" region there is a light chain modulating the ATPase activity of the heavy chain. The myosin "head" region also contains a binding side for actin.
Thin and thick myofilaments are regularly organized into the sarcomeres bounded by the Z-lines. Z-lines are build up from actin filaments, which pass through one sarcomere to another. In a transverse slice sarcomere has a hexagonal organization, where the axial structure represents a myosin filament surrounded by actin filaments in overlapping arrays, also called A-bands. During contraction the cross-bridges between actin and the "head" region of the myosin heavy chain are formed. The contraction is based on those reversible interactions and the bending of the "head" region, observed as sarcomere shortening. Nonetheless, the length of the myofilament remains essentially constant during contraction and the sarcomere shortening is due to sliding filaments passing each other.

Relaxation

Relaxation is induced by removal of the calcium from the cytoplasm back into the sarcoplasmic reticulum by the sarcoplasmic reticulum Ca^{2+} pump, better known as SERCA, which is an ATPase located predominantly in its central portion. Thus calcium dissociates from its complex with troponin C and is stored in the sarcoplasmic reticulum for subsequent release. Since this represents the only source of calcium, there is no room for gradation of contraction by changing the calcium levels.

Motor unit

A motor unit consists of one motor neuron and all the muscle fibres innervated by this particular neuron (don't confuse this with a motor pool, which represents all the motor neurons innervating one single muscle). The size of a motor unit differs in muscle types. The smallest motor unit can be found in the oculomotor muscles where precise movements are absolutely necessary. On the other hand, the biggest motor units are located within the postural muscles.

Gradation of contraction

The elementary mechanical response to the action potential is a muscle twitch. Its myographic record displays first the ascending phase, represented by gradual shortening of the muscle fibres until it reaches the peak, followed by the decaying phase standing for relaxation. The duration of the whole myographic curve differs in the different muscle types, and it depends

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on various conditions (e.g. fatigue) and external factors (e.g. temperature). The muscle twitch elicited by a single stimulus produces only a fraction of maximum shortening or tension development. In skeletal muscle, physiological gradation of contraction is accomplished in two ways: recruitment and summation.

Summation

Summation hinges on repetitive activation(s) prior to full relaxation. If the next stimulus arrives before the mechanical response is completed, both responses fuse. If the fused response is double peaked, it is called superposition (Figure 4). If the new contraction occurs during the crescent, the resulting double contraction has a single peak, clearly surpassing the single twitch. A train of stimuli during the decaying phase exerts cumulative superposition termed incomplete (undulatory) tetanic contraction. A train of stimuli during the ascending phase exerts smooth (fused) tetanic contraction.

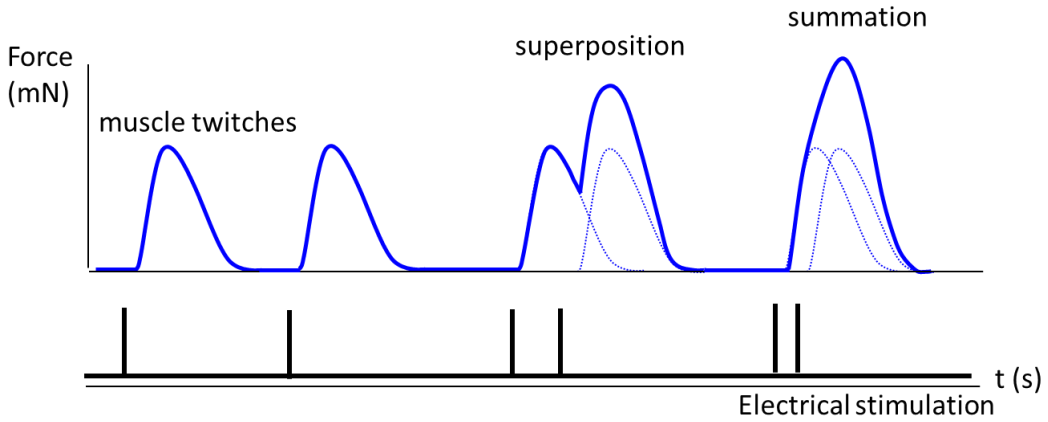

Figure: Summation: force of muscle contraction depending on the frequency of stimulation

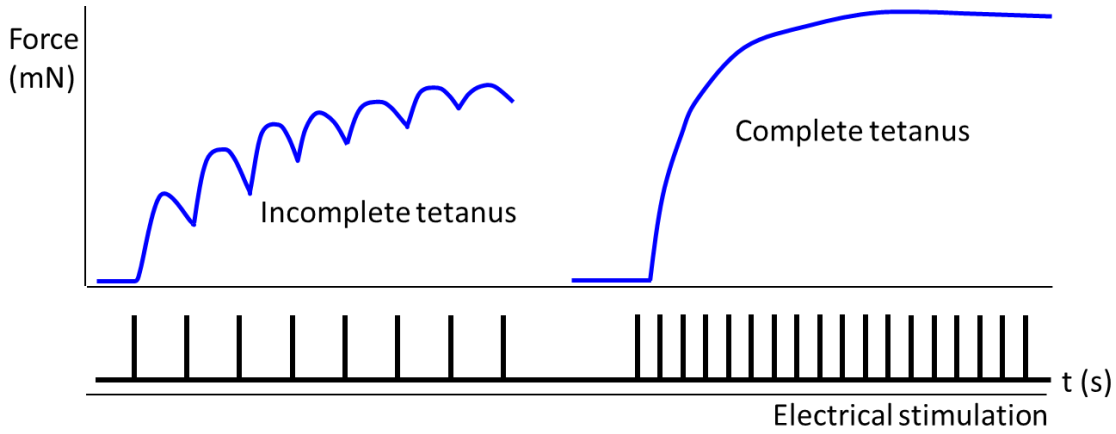

Figure 4: Summation: incomplete and complete tetanus formation

Recruitment

The more the stimulation intensity is increased, the higher the number of motor neurons simultaneously activated and hence the muscle contraction soars. This condition is known as recruitment and represents the possible gradation of contraction in the skeletal muscle based on the direct relation between the stimulation intensity and the number of activated muscle fibres (Figure 5 and 6). For this relation two terms are also defined: rheobase and chronaxia (Figure 7). Rheobase is defined as the lowest intensity able to trigger muscle

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contraction. On the other hand, chronaxie stands for the time duration necessary to provoke muscle contraction with a stimulation intensity two times greater than the rheobase.

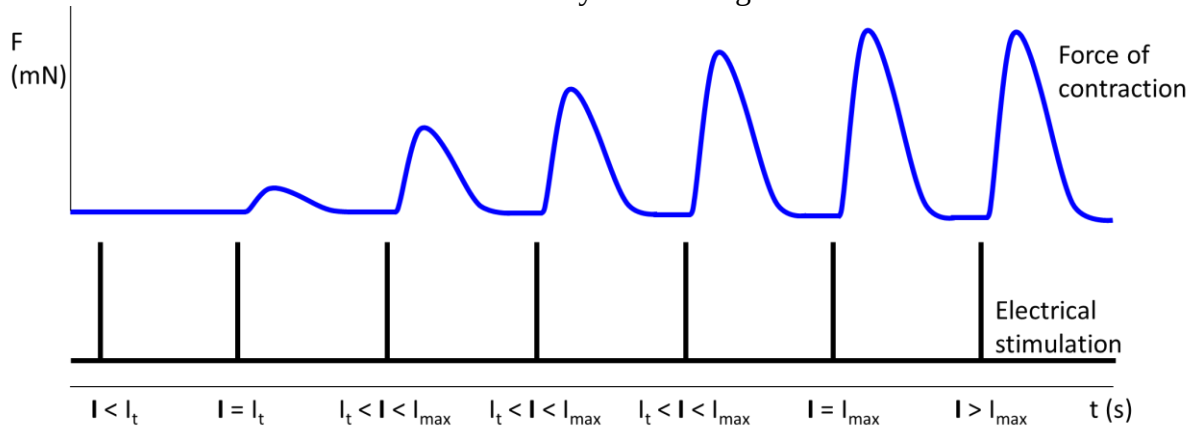

Figure 5: Recruitment of skeletal muscle. If intensity of stimulus I is lower than threshold intensity I_t, no contraction is observed. If I is higher than I_t, the first motoric units activate and muscle twitch is observed. Force of contraction increases with intensity of stimulus. When I is higher than maximal intensity I_{max}, all motoric units are recruited and muscle contraction does not increase.

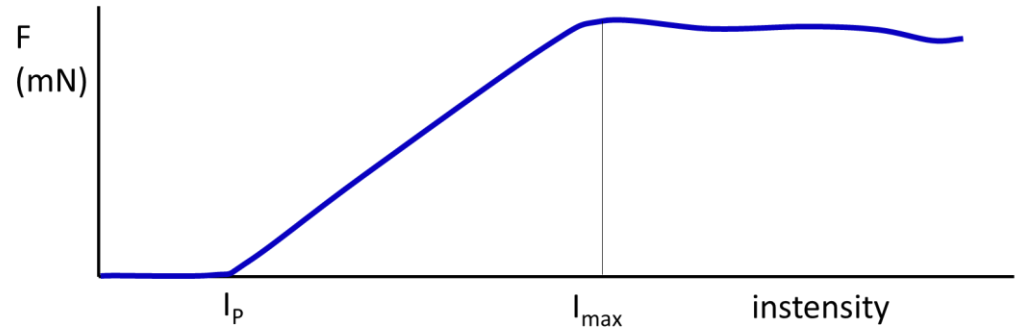

Figure 6: Dependence of force of muscle contraction on intensity of electrical stimulus

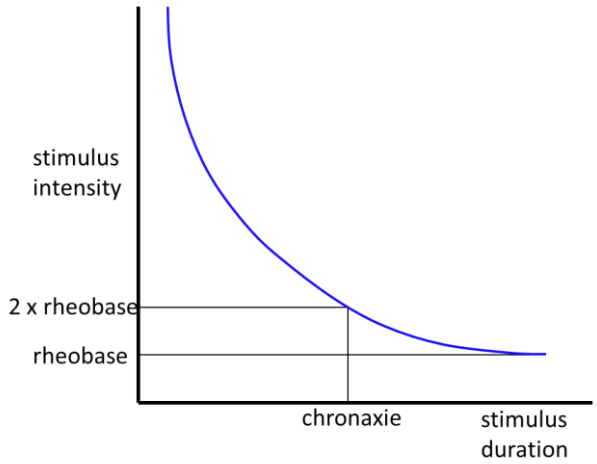

Figure 7: Dependence of contraction formation on the duration and strength of stimulus. As the strength of the applied current increases, the time required to stimulate the membrane decreases (and vice versa) to maintain a constant effect. **Rheobase:** The smallest stimulus

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leading to contraction (infinite stimulus duration). **Chronaxia**: the stimulus duration necessary for a contraction in the case of two rheobases.

2 Cardiac muscle

Whereas frequency summation and multiple-fiber summation are important mechanisms for regulating the strength of skeletal-muscle contractions, these mechanisms would not be consistent with the physiological demands of cardiac muscle. Because cardiac muscle must contract only once with each heartbeat and must fully relax between each contraction, frequency summation is precluded. Furthermore, the extensive electrical coupling between cardiac myocytes, as well as the requirement that cardiac muscle contract homogeneously, eliminates the potential for multiple-fiber summation (refracterity of cardiac action potential due to plato phase). Therefore, the strength of cardiac muscle contraction must be regulated by modulating the contractile force generated during each individual muscle twitch.

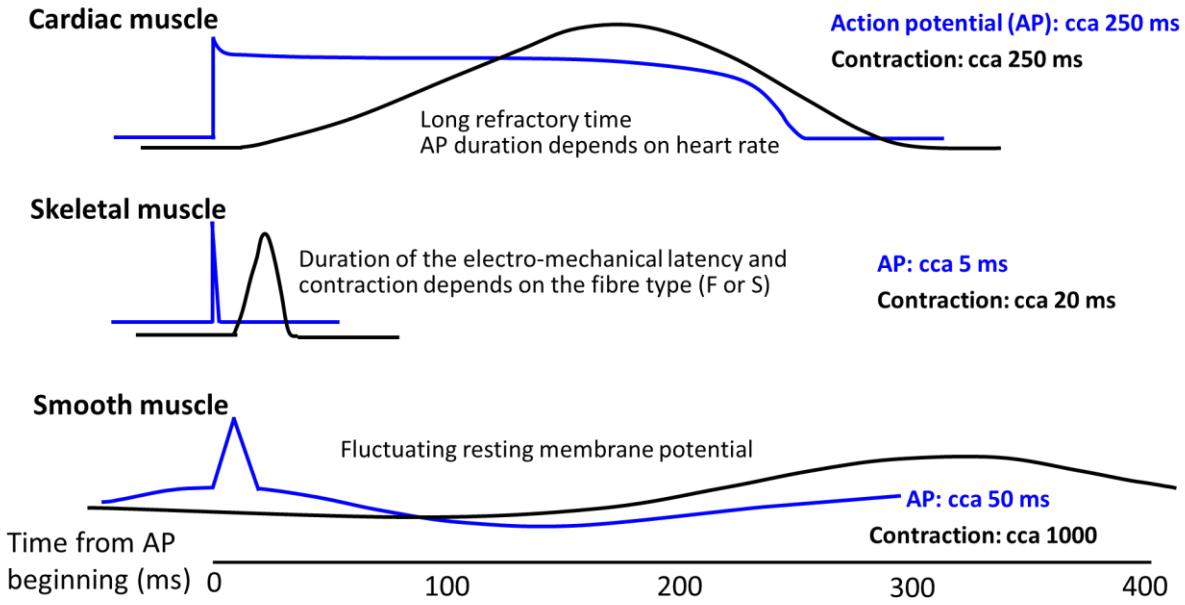

Figure 8: Comparison of action potential duration (AP, blue) and contraction (black) of skeletal, cardiac and smooth muscles. Graphs are aligned according to the AP beginnings. Amplitude of AP are not in real proportion.

Heterometric autoregulation (Frank-Starling):

Increase of the heart filling leads to stronger cardiac contraction (Figure 9)
Principles:
1) the relative position of actin and myosin during different stretch of muscle
2) fibre stretching increases sensitivity of troponin to calcium

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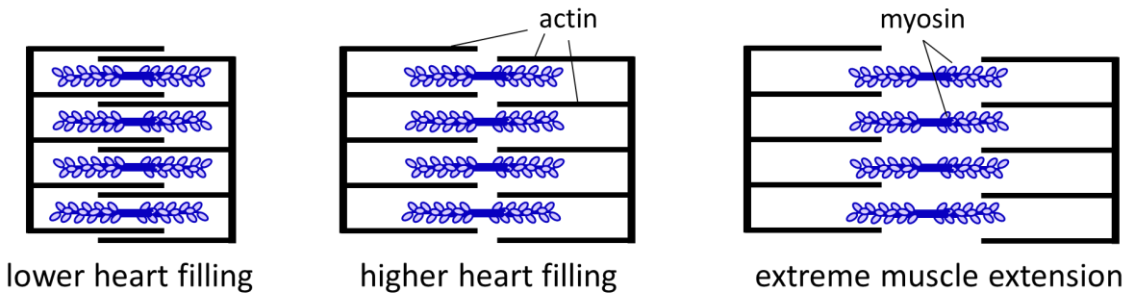

Figure 9: Frank-Starling mechanism. Lower heart filling leads to overlapping of actin (less binding places) and lower contraction. Higher heart filling enables using more binding placed on actin and higher muscle contraction. Extreme pathological extension of heart leads to decreased cardiac contractility.

Homeometric autoregulation:

Increasing heart rate leads to muscle contraction increase (Bowditch steps, Figure 10)
Principle: Increase of ratio of intracellular/extracellular calcium concentration

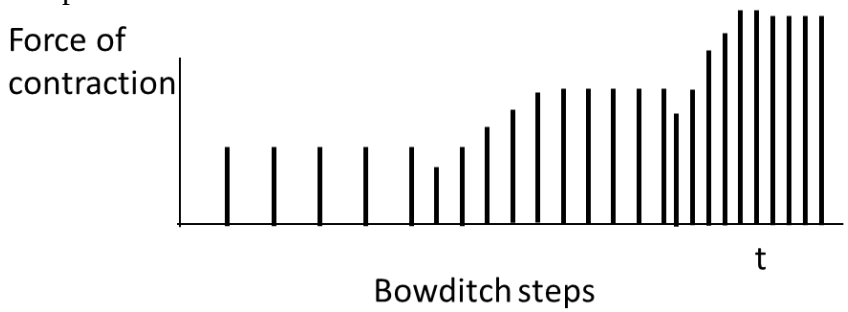

Figure 10: Bowditch steps – dependence of cardiac contraction force on heart rate. Each line represents a contraction. The first contraction after increased heart rate is lower (muscle potentiation), while other contractions increase to reach a steady state.

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name number study group

Theoretical part
Human reflexes

Reflex

A reflex is an involuntary response of an organism triggered by stimulation of a sense organ. Its structural basis is a reflex arc. The reflex arc consists of a sensory organ, an afferent pathway, a reflex central integrating station, an efferent pathway, and an effector. Reflexes are divided according to the type of sense organ into proprioceptive so-called myotatic or stretch reflexes, and exteroceptive known also as cutaneous or mucous and sensory reflexes. The proprioceptive sense organs are located in muscle or tendon as muscle spindle or Golgi tendon organ which are both stretch receptors. The exteroceptive sense organs are found in the skin or mucus membranes and are sensitive to pressure, touch, temperature and pain. The sensory organs are the most specifically developed sensors, which react only to a specific stimulus (e.g. the eye's reaction to light). The afferent pathway enters via the dorsal roots or cranial nerves the central nerve system – the spinal cord and brainstem. Afferent axons have their neuron bodies in the dorsal root ganglia or in the homologous ganglia on the cranial nerves (for instance, the nucleus principalis nervi trigemini). Information delivered by the afferent pathway is passed along directly or through interneurons to alpha motoneurons, located in the spinal cord or in brainstem. Based on the reflex centre location, reflexes are divided into spinal and brainstem reflex groups. Furthermore, according to presence of one or more interneurons, reflexes are divided into monosynaptic and polysynaptic reflexes.

Particular reflexes have anatomically strictly defined reflex arches, e.g. pathway and centre. Knowledge of them enables one to diagnose topically according to the character of the reflex response to a certain stimulus, i.e. to point out the place of nervous system disablement. The whole set of reflexes is examined in the clinic in order to get the most thorough picture of the status of the nervous system.

The response to excitement is a changed activity of motoric neurons and corresponding muscle fibres. This response is up to certain point unchangeable, but it is under the influence of higher-level structures – transmission of information from receptors (as a part of the reflex arch) as well as its integration with information from higher structures of CNS take place on the bodies of motoric neurons. The resulting motoneuron activity is then determined by summation of excitatory and inhibitory effects from all participating structures of the nervous system. Thus, it is the basis not only for a reflex, but also voluntary motoric activity.

In this exercise one should get acquainted with several reflexes that can be elicited in human beings and that are also examined in common medical practice. Throughout the reflex assessment, the following reflex features are carefully observed:

- **Elicitability of a reflex** – each reflex may be lacking in a certain percentage of healthy people;
- **Quantitative changes** – a decreased or an increased response, or an extension of the reflexogenic zone, i.e. the area from which the reflex can be elicited;
- **Qualitative changes** – the same stimulation may evoke a response of another kind than under normal conditions.

Response of the same reflex elicited on the right and on the left side are compared and differences in their quality and quantity should be noted. In some reflexes unilateral changes,

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even slight ones, are more relevant than bilateral changes. In some central nervous disturbances reflexes of another kind may appear, the s.-c. pathological reflexes that cannot be elicited in normal healthy subjects.

Proprioceptors: Golgi tendon organ and muscle spindle fibres

Proprioception provides sense of self and serves two main purposes. First, knowledge of the positions of our limbs as they move helps us judge the identity of external objects.
Second, proprioceptive information is essential for accurately guiding many movements, especially while they are being learned. Main proprioceptors: Golgi tendon organ and muscle spindle fibres.
A muscle contains two kinds of muscle fibres, "extrafusal" fibres (ordinary muscle fibres that cause contraction) and "intrafusal" fibres (in parallel with the extrafusal fibres). Some of the extrafusal fibers have Golgi tendon organs located in series between the end of the muscle fiber and the macroscopic tendon. The intrafusal fibres contain muscle spindles, which receive both afferent (sensory) and efferent (**γ-motor**) innervation.

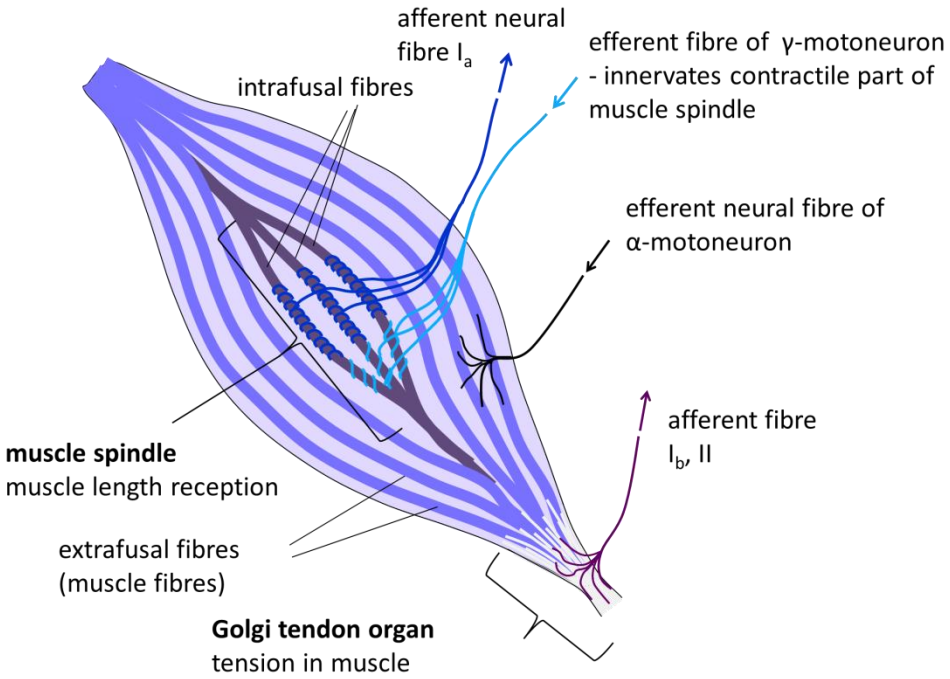

Figure: Proprioceptors: muscle spindle, Golgi tendon organ and their innervation

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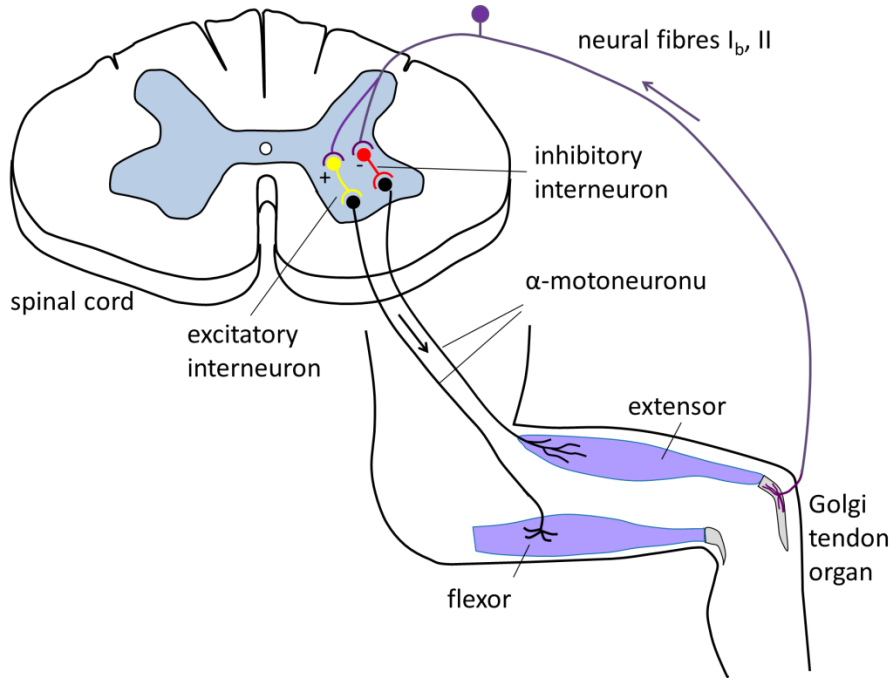

Figure: Golgi tendon reflex (inverse stretch reflex): Increase of tension in a tendon causes relaxation of a muscle (containing a Golgi receptor) and contraction of an antagonist muscle. This reflex serves as a protection from muscle and tendon damage.

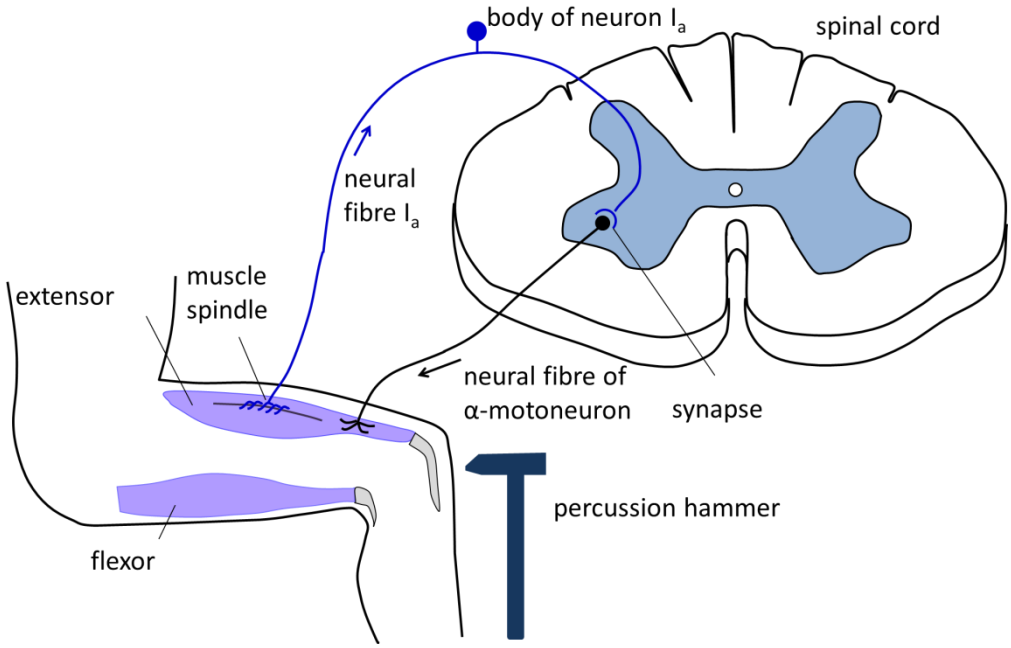

Figure: Stretch reflex: Unwanted extension causes contraction of muscle (containing muscle spindle). Reflex serves as a correction to unwanted prolongation of muscles.

The gamma loop

Alpha motoneurons (located within the anterior horn of the spinal cord) innervate muscle fibres, which generate force (extrafusal muscle fibres). Inversely, there are muscle fibres called intrafusal muscle fibres which do not contribute to the overall contractile force of the muscle. The intrafusal fibres are innervated by gamma motoneurons which are squeezed in between alpha motoneurons within the anterior horn. Gamma motoneurones make fine

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adjustments of spindle sensitivity to the demanded muscle tonus of the intrafusal fibres. The intrafusal fibres represent essential element of muscle spindle positioned in parallel to the extrafusal fibres within the muscle and are encapsulated by a spindle capsule. The central portion of the intrafusal fibres is wrapped by afferent (Ia) nerve endings. Whenever the fibres are stretched, for instance after tapping the muscle tendon with a reflex hammer, this information runs along the afferent pathway to the spinal cord and agonists alpha motoneurons are stimulated, while inversely the alpha motoneurons of antagonists are inhibited.

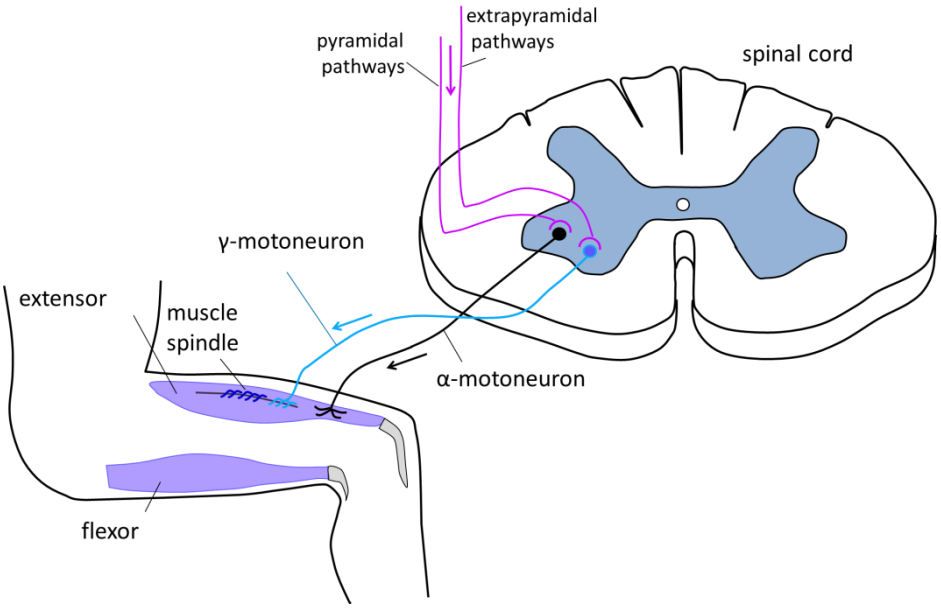

Figure: The desired change of muscle length activates simultaneously γ-motoneurons and α-motoneurons. Intrafusal and extrafusal fibres extend simultaneously and the sensitivity of muscle spindle does not change. Activity of γ-motoneurons regulates muscle spindle sensitivity.

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name number study group

Theoretical part
Achilles reflex test

Achilles reflex

The Achilles reflex (also known as the ankle jerk reflex) ranges into is categorized among. It can be elicited by tapping the tendon of the soleus muscle with a specific reflex hammer called a trigger. Once the trigger taps the tendon, the muscle itself is stretched and that selectively activates the muscle spindles located within the muscle. This activation is registered by the afferent sensory Ia fibre endings and, via the nervus tibialis, the activation is delivered to the 5th lumbar, 1st and 2nd sacral spinal cord segment where it is monosynaptically switched over to the alpha motoneurons. These activated alpha motoneurons stimulate the triceps surae muscle via efferent axons in the nervus tibialis, which is observed as an ankle jerk.

The very contraction of the muscle is preceded by membrane depolarisation of activated muscle fibres which generate the ***compound muscle action potential (CMAP)***. This potential may be recorded by means of surface electrodes (electromyographically). The duration of the signal and the interval of its delay, the latency period, are the most valuable.

According to different sites of stimulation, two kinds of reflexes may be obtained. The ***T-reflex*** is triggered by simply tapping the tendon with the reflex hammer and, thus, it is subject to various irregularities. As a result, the amplitudes of responses are not identical. The ***H-reflex*** is triggered by an electric pulse of submaximal intensity. The second method employs surface electrodes placed on the fossa poplitea close to the tibial nerve. The amplitudes of the responses are almost identical. The H-reflex is routinely employed as a diagnostic tool in neurology.

The mechanical response of the muscle, contraction and relaxation, may be recorded with a joint goniometer fixed on the calf and the foot. It is the light sensor contained in one of two plastic boxes connected by a pair of flexible optic fibres. The muscle contraction changes the angle formed by the attached boxes, and by this the deflexion of the fibres and thus the amount of light is converted to electric signal. The first derivative of the signal yields the velocity of contraction and relaxation.

The measurement of the Achilles tendon reflex was formerly used to indirectly assess thyroid function. Prolongation of the mechanical response (specifically the time when the velocity of muscle relaxation reaches its maximal value) is symptomatic for thyroid hypofunction, whereas it is shortened in hyperthyroidism. However, the timing of the mechanical response is significantly affected also by other conditions, e.g. fatigue.

Function of the thyroid gland

The thyroid gland is an endocrine gland producing hormones, which maintain the level of body metabolism optimal for the body's normal functioning. The gland itself is butterfly-shaped and straddles the trachea in front of the neck. The central part called the isthmus connects the left and right lobes together. The gland parenchyma consists of multiple acini (follicles) and parafolicular cells located in between the follicles. The parafollicular cells produce the hormone parathormone, which is involved in calcium as well as bone metabolism. Each follicle is surrounded by a single layer of thyroid cells and filled with colloid. Colloid predominantly consists of the glycoprotein thyreoglobulin.

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Thyroid hormone production is dependent on iodide intake. Iodide is absorbed in the intestine and enters the blood circulation. Subsequently it is pumped into follicular cells by an Na^+/I^- symporter and reaches a concentration 20 to 40 times as great as in the blood. Within the follicular cell, iodide is oxidised to iodine by the enzyme thyreoperoxidase and then pumped into colloid. Colloid contains the glycoprotein thyreoglobulin rich in tyrosine residues into which the iodine is incorporated. A subsequent reaction between mono and diiodotyrosine creates triiodothyronine (T3) and tetraiodothyronine (T4, so-called thyroxine). The active form of thyroid hormones is represented by T3, which arises from thyroxine through a process called deiodination mediated by thyroxine 5-deiodinase enzyme. Both thyroid hormones are transported in blood bound with thyroxine-binding protein and albumin due to their lipophilic molecule.

Effects

Thyroid hormones, like the other lipophilic hormones, are transported across the cytoplasmic membrane into the cytoplasm where they are bound to intracellular receptors, the thyroid hormone receptors. The hormone-receptor complex is translocated into the nucleus, it binds to thyroid hormone response elements in proximity of genes and regulates their transcription. Thyroid hormones affect the whole body. Their metabolic impact on transcription of glycolytic, lipolysis and gluconeogenesis enzymes combined with stimulation of Na^+/K^+ ATPase, beta receptors and mitochondrial production leads to greater oxygen consumption and thus heat production. While they are not essential for life, thyroid hormones play an invaluable role in the growth and development of immature individuals.

Hypothyroidism

Hypothyroidism represents a disorder based on the lack of thyroid hormones in adults. In children a lack of thyroid hormones leads to cretinism. Typically, a patient suffering from hypothyroidism is apathetic, exhausted and slow-witted. Due to the decreased level of metabolism, the patient gains weight, has cold limbs and his/her hair loses its strength. Another marker is represented by a specific edema called myxedema within the patient's skin in the facial and neck area. Clinical examination commonly detects a sluggish Achilles reflex, a slow heart rate and low blood pressure.

Cretinism shows the same symptoms as hypothyroidism and is accompanied by disproportional dwarfism (unequal body proportions), infertility, psychomotor retardation and difficulties in maintaining body temperature.

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name number study group

Theoretical part

Stabilometric examination of erect posture

Erect posture is a typical feature of man. It is a basic condition of walking and other human activities. Maintenance of erect posture results from the activity of the central nervous, skeletal and muscular systems. Several afferent systems provide information for control of erect posture: visual, vestibular, and somatosensory (proprioceptors and tactile receptors). Postural activity is manifested by permanent deviations of the body from the vertical axis, which results in changes of gravity-opposing muscle tone. The parameters of these deviations, their magnitude, frequency, direction etc. characterise the biomechanics of erect posture and form the basis for determining disorders of it. In neurology, orthopedics and otorhinolaryngology the erect posture is often evaluated by a mere observation. This valuation is only approximate since no recording of body movements is used. Stabilometry on the other hand gives an exact record of postural activity. The excursions can be recorded over time as a stabilogram, or in vector presentation as a statokinesigram.

The stabilometry examination enables objectively evaluating the stability of erect posture in man during various tests (e.g. Bracht–Romberg's test in neurology) and the effectiveness of vestibular control of erect posture; to record vestibular responses on galvanic and thermal stimulation; and to train the postural control by means of feedback information during rehabilitation and in various sports. The stabilometer measures the moments of supporting forces (ground reaction forces) of a standing subject in two perpendicular directions on the horizontal plane. It uses mechano-electrical transducers with automatic compensation of the subject's mass on the stabilometric signals.

The centre of mass is a point that represents the average position of the body's total mass. When standing upright it is located in the abdomen approximately 20 mm in front of the second lumbar vertebra. Although gravity pulls on all body segments, the net effect on the body acts through the centre of mass. The force of gravity is opposed by the ground reaction forces, which push upward against each foot in a standing subject. The centre of pressure (COP) is an imaginary point on the ground, through which an organism exerts the resultant ground reaction force on the support surface. The ground reaction force vector originates in COP and aims upwards, while the force of gravity vector originates in the centre of mass and aims downwards. For the body to be in static equilibrium, the force of gravity and the ground reaction force must be equal and opposite, and the centre of pressure must be directly under the centre of mass.

In a stabilometric test the motion of COP is recorded within the X and Y coordinates of the horizontal plane during a time period, producing a statokinesigram. The cross point of coordinates is situated in the centre of the stabilometer plate, positive values representing deviations to the right and forward on the X and Y coordinates, respectively. The following parameters characterize the stabilometry examination:

1) Mean COP X, Y (mm) is the mean value of X coordinates and mean value of Y coordinates of all points of the statokinesigram. It depends not only on the position of the subject on the stabilometer plate but also on inclination of his/her body.
2) Mean distance from the centre (mm) is the average deviation of COP position from the mean COP X, Y in left-right (X) and front-back (Y) directions. It is proportional to the size of the area defined with the movement trajectory.
3) Mean velocity (mm/s) represents the average speed achieved by moving COP. It characterizes the extent of muscular effort in maintaining an erect posture.

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4) X, Y-axis movement (mm) is the total length of the path that the COP follows in the left-right (X) and front-back (Y) directions. It provides information about the prevailing direction of movement and is directly proportional to the actual length of trajectory.

All these parameters (with the exception of Mean COP X, Y) describe the overall stability. Increased values indicate decreased postural stability. In our practical the parameters enable us to assess the role of afferent systems in the process of postural control.

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