BITalino (2. LF UK)

Theoretical preparation

Electromyography (EMG)

Electromyography (EMG) is a diagnostic method used to record and assess the electrical signals produced by skeletal muscle activity. An instrument called an **electromyograph** is used for the measurements and the curve obtained describing the electrical signals during the work of the muscle is called an electromyogram. The higher the peaks of the **electromyogram**, the more intense the electrical potentials are captured and the harder the muscle works. Using this method, the muscle as a whole is not imaged, but only smaller functional units of the muscle called **motor units** (see below).)[1][2].

In practice, two basic electromyographic methods are used - **surface EMG** and **subsurface (intramuscular) EMG**.

Surface EMG

Surface EMG is a non-invasive method of recording electromyographic impulses. Surface electrodes are used to detect muscle activity and are attached to the skin of the subject using adhesive surfaces or patches. **A minimum of two electrodes** (+ and - electrode) must be used for the measurement, but in practice at least three are used - two sensing the difference in electrical potential between the electrodes (+ and - electrode) and one reference (placed at a point of zero potential, most typically a bone near the area to be measured).

Due to the size of the electrodes, not only single motor units can be measured, but **always several motor units** at the same time. **The advantage of this method is its non-invasiveness and easier application**, the **disadvantages** are related to the impossibility of measuring single motor units. Surface EMG can also be used to measure the activity of only superficial muscles and its accuracy is largely influenced by (a) the condition of the skin of the subject, (b) the amount of tissue between the measured muscle and the skin (especially adipose tissue). The method generally shows **less variation** in younger people compared to older people.

Initially, the method was considered clinically inappropriate, but new evidence suggests that the method can be used for **basic detection of some muscle diseases.**

Subsurface EMG

Subsurface EMG also allows **measurement of deeper muscle groups** with greater accuracy, as the area scanned can be limited to a single motor unit. In extreme cases, even a single muscle fibre can be measured - using the **SFEMG** (**S**ingle-**F**iber **EMG**) method. Needle or wire electrodes are used for surface EMG. **The needle electrode can be precisely inserted into the selected motor unit**, but it may only be present in the muscle for a short time, and more extensive muscle movements greatly increase its sensing error. On the other hand, **wire electrodes** can be in the muscle for longer periods of time, more pronounced muscle contraction does not significantly reduce the accuracy of the measurement, but the electrode cannot be placed with the same precision as a needle electrode. **The disadvantage** of the surface EMG method is the painful insertion of the electrodes and the method also requires more skilled personnel.[2][3].

Today, EMG is not only used as a **diagnostic method**, but also finds wide application in the field of **biotechnology, bioinformatics and rehabilitation**. For example, robotic prostheses can be controlled using the EMG signal. Systems controlled by the EMG method are generally called **M**yoelectric **C**ontrol **S**ystems (**MCS**s).

Mechanism of skeletal muscle contraction control

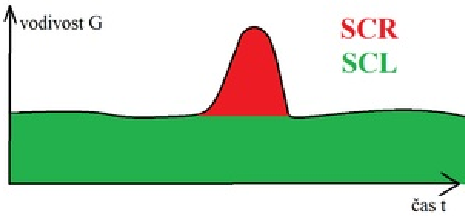
Skeletal muscle is controlled by **motor neurons**. The terminal portion of the motoneuron axon branches and the individual branches attach to muscle fibres. The point of contact between the neuron and the muscle is called the **motor plate**. At the same time, the term **motor unit** is introduced, which is defined as the number of muscle fibres innervated by a single motoneuron. The fewer fibers innervated by a single neuron, the finer motor skills a given muscle can perform[6].

> Once a neuron is activated, an **action potential** (AP) propagates through its axon and is transmitted to the muscle fibers in the form of a neurotransmitter at the chemical neuromuscular synapse. Once the neurotransmitter (specifically acetylcholine) binds to receptors located in the sarcolemma (the cytoplasmic membrane of the muscle fiber), **synchronous depolarization** of all muscle fibers of the motor unit occurs, generating a muscle **action potential** that propagates further down the sarcolemma of each fiber. As a result, **the Ca-channels of the sarcoplasmic reticulum** (endoplasmic reticulum in muscle elements) **open** and muscle contraction is performed[1][6].

The EMG method captures the resulting Motor **U**nit **A**ction **P**otential (MUAP) using electrodes and its waveform is recorded as an electromyographic curve[1][2].

Electrodermal activity (EDA)

Mechanism of the body's response to stress stimuli and the principle of EDA sensing



Simplified diagram of the conductivity graph.

Smooth muscles, heart and glands in the human body are controlled by the **autonomic or autonomic nervous system** (ANS). This system is not directly influenced by our will and is divided into two parts, **the sympathetic and parasympathetic**, which generally act in opposing ways.

The sympathetic system is responsible for controlling the body's rapid response and mobilization of energy resources for escape or defense (fight or flight) in stressful situations[2].

The parasympathetic is responsible for longer-term energy acquisition and storage from food (rest or digest) and comes into play during digestion and rest. The autonomic nervous system is overridden by centers in the spinal cord, brain stem, and hypothalamus[2].

Among other things, **the sympathetic system** triggers a response in the sweat glands located in the skin. Most sweat glands on the body increase sweat secretion at high body temperature, and evaporation of sweat from the body surface leads to cooling. However, **sweat glands** are found to an increased extent on the palms of the hands, the soles of the feet and the armpits, which respond to emotional stimuli, especially in **stressful situations** (fear, anger, pain, anxiety), and similarly to increased **cognitive load** (memory, rapid information processing, orientation). The evolutionary advantage of this mechanism is still a matter of debate. Because sweat contains ions such as Na+ and K+, it is a potent electrolyte, and when secreted from the sweat glands, it **increases the skin's conductivity**, i.e., decreases its electrical resistance. This change in skin conductance can be measured either by a small current (or applied voltage) sent by a measuring device (**exosomatic method**) or by sensing the electrical activity of the skin without applying an external current (**endosomatic method**). The exosomatic method is used to measure the electrical resistance of the skin (Skin Conductance), while the endosomatic method is used to measure the electrical potential of the skin (Skin Potential). In most of today's instruments the exosomatic method is used, this method is also used by the BITalino (r)evolution instrument, the EDA curve is obtained by measuring the electrical resistance of the skin under constant electric current[3]. The collective name for these changes in the skin is **electrodermal activity**, or **EDA**[1][4].

Depending on the method of measurement, we can observe **normal**, **non-stressed**, **tonic electrodermal activity** (**SCL** - **S**kin **C**onductance **L**evel / **SPL** - **S**kin **P**otential **L**evel) when the test subject is at rest and stressed, **phasic electrodermal activity in response to a stimulus** (**SCR** - **S**kin **C**onductance **R**esponse / **SPR** - **S**kin **P**otential **R**esponse). In the bipolar electrode connection (two electrodes) used in most devices, the SCL and SCR versus time are part of a single line on a graph, with the SCL appearing as a more or less horizontal line and the SCR as a sudden rise in conductance followed by a sudden descent. The entire SCR curve generally returns to its original position within 1 to 3 seconds after a single isolated stress stimulus. Similarly, the delay between the stress stimulus and the change in skin conductance (visible in the EDA curve) is usually another 1 to 3 seconds. This delay is due to the time lag between the following processes: s**ensory perception of the stimulus → processing of the sensation in the CNS → parasympathetic conduction → increased sweat gland activity**[1].

Skin conductance can be influenced by external factors such as temperature, humidity, time of day, season and internal factors such as medication, drugs, age, gender or phase of the menstrual cycle[1].

Practical applications of EDA

Psychologists were among the first to use devices measuring electrodermal activity in the early 20th century, most notably **Carl Gustav Jung** (in the **word association** method). Indeed, EDA sensing makes it possible to observe the stress factors acting on a person and to measure the degree of stress quantitatively. Today, among other things, these devices are used for remote monitoring of patients affected by **autism**. These people often find themselves in stressful situations because they cannot communicate with people in their environment, and the small measuring devices, in the form of wristbands, send data directly to the doctor, who can phone the family, for example, to find out why the patient is in a state of disorder. It has been found that these devices can also detect an impending **epileptic seizure** with little advance notice. EDA measurement is also one of the components of the **polygraph** (the so-called "lie detector"), used especially in criminalistics. Last but not least, we can mention one of the more bizarre uses, in the form of the so-called "E-meter," used by members of the Scientology movement[1][5].

Practical part

General instructions

In order to work with BITalino (r)evolution, it is necessary to use a computer with Bluetooth. Download Google Chrome on your computer, which is required to run the program. The OpenSignals (r)evolution program is available as a free download for all operating systems here: http://bitalino.com/en/software . The basic version of the program is free, however, you must purchase the premium version to access all features (the free version is sufficient to complete both tasks). More detailed information on BITalino (r)evolution can be found here (https://cs.wikibooks.org/wiki/BiTalino_(r)evolution_(manu%C3%A1l)).

1. After installing the program, **turn on BITalino** by sliding the black lever on the edge (see photo). After switching on, a flashing green light is visible (see photo).
2. **Connect BITalino to your computer** - turn on Bluetooth and connect to BITalino. The PIN for connection is

1234.
3. **Open the OpenSignals program**. For better orientation in the program we recommend watching the demo video, which is also available on the above attached link. This video introduces the premium version of the program.
4. **Set the BITaline scan rate to 100 Hz using OpenSignals**. After opening the program, click the icon with the green circle in the middle to open a list of known and unknown BITalino devices in your area. Now click on the icon of the connected BITalino and change the frequency (parameter marked: Sampling rate) from the preset 1000 Hz to 100 Hz.
5. **Plug an extension cable into one of the 6 ports of the BITalino** (see photo). As each port has its own window in the program, it is necessary to make sure that the window is opened with the same port number (which is not indicated on the box!). For the easiest orientation in the ports, we recommend to use port 1 at all times.
6. **Connect the sensor to the cable**. Make sure **to connect the correct sensor** (i.e. EDA sensor in case of electrodermal activity sensing and EMG sensor in case of electromyography). Also make sure **to connect the sensor in the correct direction** (the stamped letters on the sensor packaging must be oriented correctly when viewed from the electrodes).
7. **Connect the appropriate electrode cables**, which are described in more detail in the task, to the free sensor socket.

Lever for switching on and off

Task 1 - Determine the function of the biceps brachii and triceps brachii during specific movements using surface EMG

Using a BITalino device with surface EMG electrodes attached, verify which movements (see workflow) result in the most significant involvement of the biceps brachii and triceps brachii muscles.

Which type of push-ups is best for strengthening the triceps brachii? What anatomical position must the forearm be in for the biceps brachii to be significantly involved in flexion at the elbow joint? What is the cause of its low to no activity in other forearm positions?

Instructions

1. Following the general instructions, **prepare the BITalino and connect the EMG labeled sensor**.
2. **Attach the three-electrode cable** (see photo) to the sensor and **clip the 3 electrodes in place** using the tacks. Note: When working with the three-way sensor, **make sure to position the electrodes correctly! The negative and positive sensor** (marked in black and red respectively at the point of cable separation) must be placed on the designated muscle, the white electrode serves as a reference and is connected to the bone just under the skin. In this case, glue the reference electrode to the olecranon of the ulna. Placing the reference electrode on the electrically inactive area is essential for adequate measurement results!
3. **Stick the electrodes on the muscle to be examined** (the order of examination of the biceps and triceps brachii is arbitrary). Try **to stick the electrodes on the long head of the muscle** in question (see photo)
4. After sticking the electrodes, **the subject starts to exercise according to the following instructions** (meanwhile the examiner observes the changes in muscle activity - as in the case of the free version of the EDA, it is not possible to view the recording retrospectively)

Indication of switched on BITaline with flashing diode

Examination of the activity of the biceps brachii muscle during elbow flexion movements (m. biceps brachii)

1. **Find a body that can be grasped with one hand** (with a weight of at least 3 kg - for example a backpack loaded with books)
2. **Stand in the basic anatomical position** (forearm in supinated position), grasp the body in the hand on the arm with the electrodes attached and **perform at least 10 flexions** at the elbow joint; **observe the changes in the EMG curve values**
3. **Perform partial pronation of the forearm** (with the palm of the hand pointing downwards with the pinky edge) and again **perform several flexions at the elbow joint while observing the EMG**
4. Place the **forearm in a fully pronated position** and **repeat the flexion movements again**
5. **Evaluate the data** and **answer the questions**

Examination of the activity of the triceps brachii during different types of push-ups (m. triceps brachii)

1. **Assume a supine position** ('push-up')

2. **Perform** approximately **ten push-ups with a wide arm stance** (i.e. arms well over shoulder width, elbows pointing away from the body during the push-up)
3. After a short pause, **perform another 10 push-ups**, this time with **a classic hand position** (hands shoulder width apart, elbows pointing away from the body during the push-up)
4. Again, let the subject rest briefly and repeat the **set of 10 push-ups with a narrower grip** (hand spacing slightly less than shoulder width, elbows pointing along the body)
5. After another break, **do 10 push-ups in a diamond grip** (hands are placed close together, so that the two opposable index fingers and thumbs are always touching each other, forming a triangle between them)
6. **Provide the subject with a stable chair** (one that does not tip over when resting on its edge)
7. **The subject places his/her heels on the floor, hands on the edge of the chair** (with arms behind his/her back - standing upright) and performs the last set of ten, this time triceps push-ups with the grip behind his/her back
8. **Evaluate the data** and **answer the questions**

Task 2 - detecting peripheral nervous system activity when exposed to specific environmental stimuli

Using a BITalino with attached EDA electrodes, determine which stimuli elicit the greatest stress response in the subject (only expose the subject to **pre-arranged and voluntarily agreed** stimuli - see instructions).

Record which stimuli increased skin conductance the most and which ones left the subject calm.

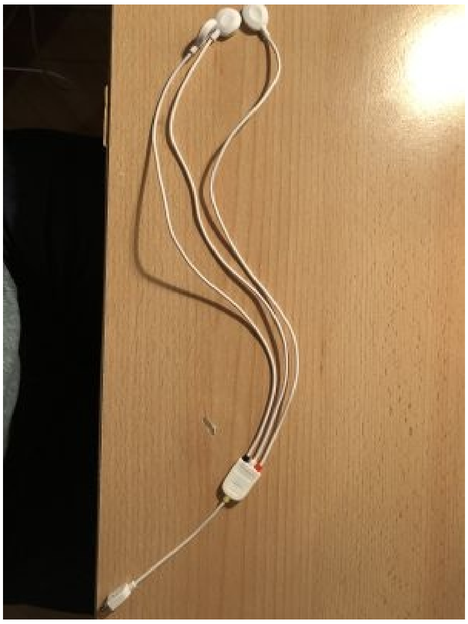
In the discussion, write down which external factors (environment) and which internal factors (patient) may have influenced the results of the measurements, and try to briefly assess the patient's sensitivity to stress (i.e. how the skin conductance increased relatively to the resting value during the stimuli) on the basis of the findings.

If you have included both categories of stimuli (one from group A, B, C, F and the other from group D, E), also answer the question whether the patient is aroused more by the stress stimuli or by the cognitive load.

Extension cable

Instructions

1. According to the general instructions, **prepare the BITalino and connect the sensor with the EDA label**.
2. **Attach the 2-electrode cable to the sensor and clip the 2 electrodes together with the tacks**
3. **Peel the protective sticker** from the electrodes and **stick them on the soap-washed hand** of the subject as shown (one electrode on the hypothenar muscles, the other on the thenar muscles; see photo)
4. **Start the measurement** by clicking on the red circle icon
5. **With the subject's consent**, **select at least three** of the following stress stimuli:
   - A) Holding the breath for at least 20 seconds
   - B) Strengthening the abdominal muscles in a static "plank" position for at least 30 seconds
   - C) Painful stimulus in the form of pinching the ear or squeezing the trapezius muscle
   - D) Testing the subject for several minutes on a difficult subject, e.g. anatomy
   - E) solving puzzles or doing homework
   - F) Watching at least two videos on the Internet with titles such as "top jump scares," "short horror movie," "disturbing video," "uncanny valley"
   - Notes: Stimulus D requires one additional examiner, for a total of three participants. Stimulus F is better done with headphones in the patient's ears and in a darkened room.



Three-way sensor (red - positive electrode, black - negative electrode, white - reference electrode)

Subject the subject to the selected stimuli and closely monitor the recorded graph in real time

Evaluate the measured data and answer the questions

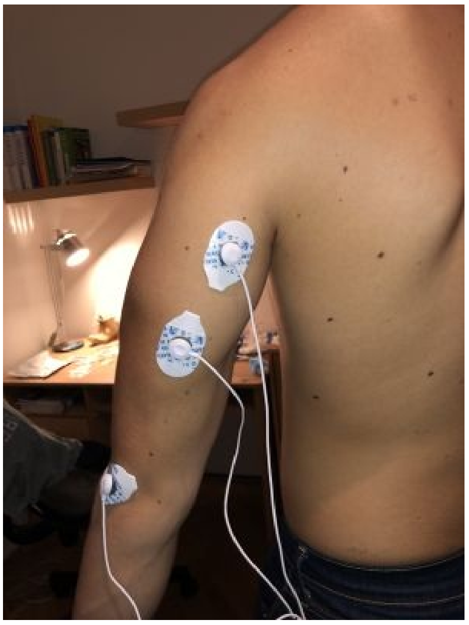
References

1. HOROWITZ, Stephen H. Overview of electromyography. *UpToDate* [online]. 2018-08-10 [cit. 2018-11-29]. Dostupné z: https://www.uptodate.com/contents/overview-of-electromyography
2. ↑ Skočit nahoru k:a b c d e f https://en.wikipedia.org/wiki/Electromyography
3. ↑ Skočit nahoru k:a b c https://cs.wikipedia.org/wiki/Elektromyografie
4. ↑ https://www.youtube.com/watch?v=LOFUTNEgrv4
5. ↑ Chowdhury, R.H.; Reaz, M.B.I.; Ali, M.A.B.M.; Bakar, A.A.A.; Chellappan, K.; Chang, T.G. Surface

Electromyography Signal Processing and Classification Techniques. *Sensors* 2013, *13*, 12431-12466.
6. ↑ Skočit nahoru k:a b Vajner, Luděk, Jiří Uhlík a Václava Konrádová*. Lékařská histologie I.: cytologie a obecná histologie.* 2., upravené vydání. Praha: Karolinum, 2018. ISBN 978-80-246-4107-2.
7. ↑ Skočit nahoru k:a b c d e STERN, Robert Morris, William J RAY a Karen S QUIGLEY. *Psychophysiological recording*. 2nd ed. New York: Oxford University Press, 2001. ISBN 0195113594.
8. ↑ Skočit nahoru k:a b c Grim, Miloš a Rastislav Druga. *Základy anatomie*. 2., přeprac. vyd. Praha: Galén, c2014. ISBN 978-80-7492-156-8.
9. ↑ Electrodermal Activity (EDA) Sensor Data Sheet. Dostupné z:http://bitalino.com/datasheets/REVOLUTION_EDA_Sensor_Datasheet.pdf
10. ↑ Zangróniz R, Martínez-Rodrigo A, Pastor JM, López MT, Fernández-Caballero A. Electrodermal Activity Sensor for Classification of Calm/Distress Condition. *Sensors (Basel)*. 2017;17(10):2324. Published 2017 Oct 12. doi:10.3390/s17102324
11. ↑ Petr, J., 2017. Pod elektronickým dozorem. *Zázraky medicíny (6/2017). Brno.* Str. 6

1. HOROWITZ, Stephen H. Overview of electromyography. *UpToDate* [online]. 2018-08-10 [cit. 2018-11-29]. Dostupné z: https://www.uptodate.com/contents/overview-of-electromyography
2. https://en.wikipedia.org/wiki/Electromyography
3. https://cs.wikipedia.org/wiki/Elektromyografie

Connecting EMG sensing electrodes to the long head of the biceps brachii muscle.



Connection of EMG sensing electrodes to the long head of the triceps brachii muscle and reference electrodes to the olecranon.

Electrode placement for measurement EDA.