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COMPARISON OF BIOMECHANICAL SYSTEMS FOR EVALUATION OF LOCAL MUSCULAR LOAD

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Abstract

The paper deals with the use of biomechanical systems for evaluation of muscular load of upper limbs. The study is focused on comparing EMG Holter with the EMG Biometrics DataLog. EMG Holter is the only approved device in the Czech Republic. The aim of the study was to compare the results of these two devices for sensing electrical potential in the muscles of the forearm of the upper limbs in the most commonly used positions of grip and compression of the object.

Keywords: EMG; local muscular load, Holter, Biometrics DataLog

1. Introduction

Nowadays many people are facing the problem of incapacity for work, which is a problem not only for enterprises but also for their employers. It can be caused by many reasons, either biological, chemical or physical. Occupational disease may be temporary or permanent, but it is clear that a situation where a worker is indisposed is not a pleasant situation for him or for the company for which he works. In the Czech Republic, 1 370 occupational diseases were reported in 2017 [1]. Compared to 2016, the total number of reported occupational diseases increased by 73 (ie 5.6%). [2] The article deals with the use of biomechanical systems for evaluation of local muscular load of upper limb. The most common damage to health at work and also the most recognized occupational diseases of all blue-collar is the one-sided long-term overloading of the upper limbs. Compliance with hygienic limits of local muscle load is crucial for the operation of the entire industrial or manufacturing company. Overloaded workers do not perform standardized services and are often tired which leads to greater waster and increased business costs. The topicality of this topic is mainly due to the continuous expansion of production companies and the filling of new jobs. In the Czech Republic, Holter is the only device which is approved and used by the legislation. The study focused on comparing this device with the EMG Biometrics DataLog device. The aim of the study was to compare the results of these two devices for sensing the electrical potential in the muscles of the forearm of the upper limbs in the most commonly used positions of grip and compression of the object.

2. Metodology

The aim of the research was to compare the output data from the EMG Holter and Biometrics DataLog devices and to find out whether these outputs are comparable or if there are any differences and what are the possibilities of their use. A series of identical measurements was performed on selected people, in the same hand positions and under identical conditions. The measurements were carried out using the above-mentioned instruments. Using the sensing electrodes of both instruments, the electrical potential of the loaded muscles (flexor and extensor) of the forearm of both arms was sensed. The force of the compression was used to load the muscles, it was measured by dynamometer in individual positions of the arms and wrists. Positions were chosen to correspond to the most commonly used gripping and pressing positions not only in the working environment but also in everyday life. The basic positions for measuring EMG arms were (you can also see it on the figure below):

- hand with elbow at right angle as close to body as possible,
- overhand grip,
- underhand grip,
- stretch arm forward.

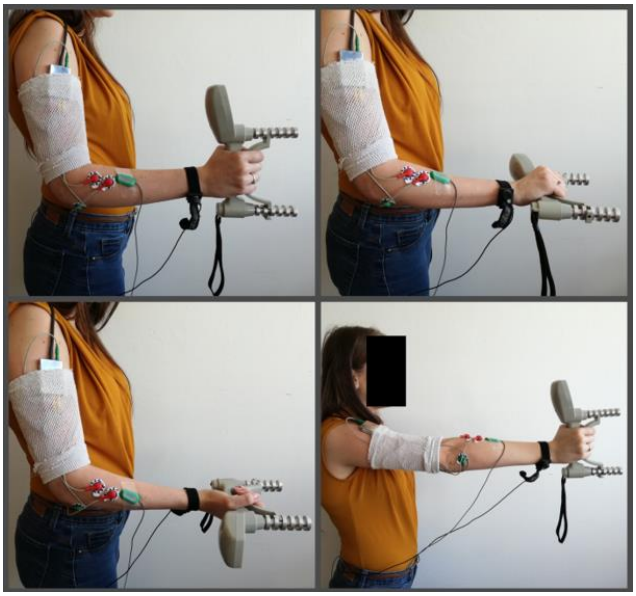

Fig. 1. Defined upper limb positions

The force of squeeze force was chosen according to sex and to [3]. The pressure range for women is from 10 Kg to 30 Kg, for men from 10 Kg to 40 Kg. The research was accomplished on 20 examined people. 15 men and 5 women were measured in the age range from 23 to 27 years.

3. Measuring devices – electromyography

The essence of electromyography is the measurement of electrical potentials that arise from the activity of skeletal muscle. An electromyograph, an instrument that records electrical muscle activity, is used for examination. The electromyograph which is consisted of a monitor, evaluator, source of electric pulses and two surface electrodes. There are two kinds of electrodes – stimulation and registration. Stimulation electrodes conduct an electrical pulse that is transmitted by the nerve and ends by contracting the muscle. The recording electrodes sense the action potential of the motor units (muscle). There is also grounding electrode, which serves as a short circuit for disturbing currents from the mains. The most often is ribbon or rectangular electrode [4], [5], [6] There are several types of electromyography – surface electromyography (conductive) and needle electromyography, in which a needle electrode is inserted into the respective muscles. The research was focused on surface electromyography, especially using EMG Holter and EMG Biometrics DataLog.

3.1. EMG Holter

EMG Holter is a device that has been developed to evaluate the local muscular load of the upper limbs, specifically the forearm muscles. It senses electrical potentials from the loaded muscles during the work. It also allows recording of four EMG signals and also pulse frequency. During EMG scanning, integral values and frequencies of EMG signals are stored. The device also includes a free DC channel for connecting another external module for example for temperature measurement. All measured values are stored in the internal memory of the instrument, which allows to record data from all 4 channels for up to 17 hours. The data stored in this way is transferred to the computer for further evaluation after the

measurement. [7], [8] Sensing electrodes are used to sense electrical potentials. The electrodes are attached to the skin of the selected muscle by disposable gel patches. However, they can still be fixed with medical adhesive tape. The whole assembly - the cases of amplifiers, cables and electrodes is secured to the body of the examined person by means of a flexible bandage. [7] EMG Holter is the only device which is approved and used by the legislation in the Czech Republic. Results of the measuring and also the Czech legislation for the local muscular load is in Fmax. Fmax is the force that the investigated person is able to achieve with the maximum voluntary effort exerted by specific muscle groups.

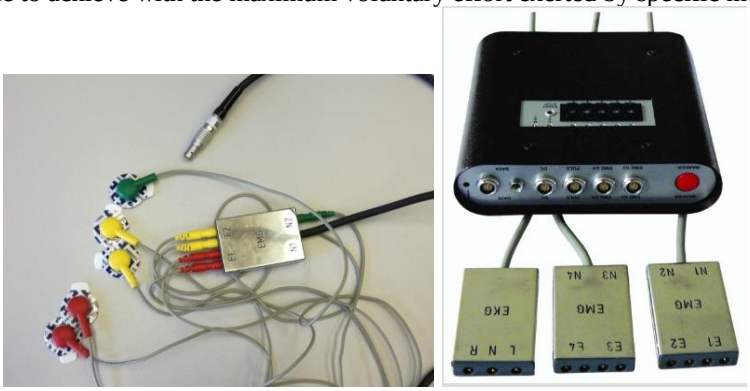

Fig. 2. EMG Holter with electrodes [7]

3.2. EMG Biometrics DataLog

It is a comprehensive package of sensors and instruments for static and dynamic measurements in clinical, office or other work environments. They contain a portable data acquisition unit MWX8 DataLog. DataLog itself is the latest technology in the field of data acquisition, data transmission and monitoring of human performance in industrial ergonomics. This device includes a small lightweight battery, a color graphic LCD display, a joystick, a microSD card interface and a wireless PC connection via Bluetooth. During the measurement, it can be placed on the shoulder, leg or torso in such a way that it does not disturb the observed person. Various goniometers and sensors can be connected to the device. [9] Biometrics EMG Sensors offer a variety of portable sensor types which are available in three versions [9]:

- Surface sensor EMG, which has integrated electrodes with fixed distance of 20 mm. No skin preparation or conductive gels are required with this sensor. It is simply applied using a specially cut adhesive tape directly to the muscle.
- Wireless surface sensor EMG with integrated electrodes up to 40 meters.
- Wireless EMG Amplifier, which uses disposable electrodes and has variable electrode spacing, the maximum spacing between the electrodes is 170 mm, the minimum depends on the size of the electrodes used.

EMG Biometrics DataLog is not allowed for authorized measuring of local muscular load in the Czech Republic. Results are mV.

Fig. 3. EMG Biometrics DataLog with electrodes [9]

4. Experiment progress

Following chapters deal with the course and evaluation of experiments.

4.1. Measuring progress

EMG Holter and EMG Biometrics electrodes were glued to the examined muscles – extensors and flexors on both hands.

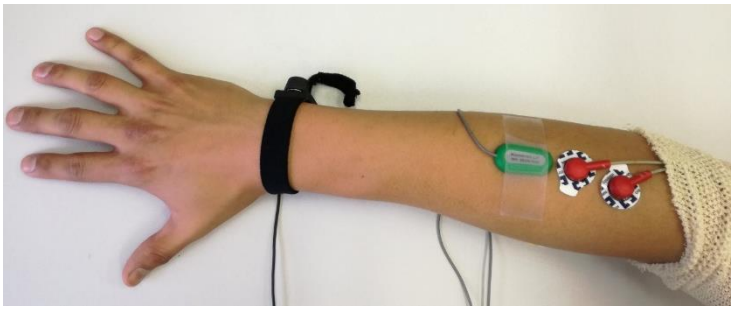

Fig. 4. Electrodes on extensor of right hand

The principle of measurement was to compress the grip force on dynamometer JAMAR PLUS+ to different forces in four basic hand positions. In the design of the experiment, the positions of the arms and wrists including the loaded forces were chosen. However, at the beginning of the measurement, it was found that not all test subjects have enough force for the load cell clamping ranges defined by us, or are those forces are too small - for example, for men. Because of this, these ranges have been modified and achieved individually for each person during the measurement. Squeezing forces was gradual, due to the recording into the elevation table and a gradual loading of the monitored muscles. In the starting position – hand with elbow at right angle as close as to body is possible, the men squeezed 10 kg, 20 kg, 30 kg, 40 kg, 50 kg and MAX. Women category was slightly less - 10 kg, 20 kg and MAX. These values were individually derived from the squeezed Fmax at the start of the measurement. There was a 10 – 20 second rest between individual forces and positions. It was necessary to check the correct position of the wrist - in a plane, without rotation and elbows as close to the body. In the second position – overhand grip, a force of 10 Kg, 20 Kg, 30 Kg and Max was squeezed by men and only 10 Kg, 20 Kg and MAX were squeezed by women.

Next position were the underhand grip. The elbow of the subject was still at right angles, but with the palm up, still with the elbow as close to the body as possible. In this position, 10 Kg, 20 Kg, 30 Kg, 40 Kg and MAX were squeezed by men, and only 10 Kg, 20 Kg and MAX by women.

The last position were stretch arm forward when the arm makes an angle of 90°to the body. In this position, 10 Kg, 20 Kg, 30 Kg, 40 Kg and MAX were squeezed by men, and only 10 Kg, 20 Kg and MAX by women.

The measurement of one hand took about 15 minutes, the whole measurement about 30 – 40 minutes.

4.2. Data processing

After completing the measurement and storing the scanned data, it was necessary to process the data. Values are output from the DataLog (Biometrics) as a read-only notebook. The document is filled with information about the beginning and end of the measurement and the channels used. To view the amplitude, you must open this document in DataLog. Red amplitude is for EMG 1 and green for EMG 2.

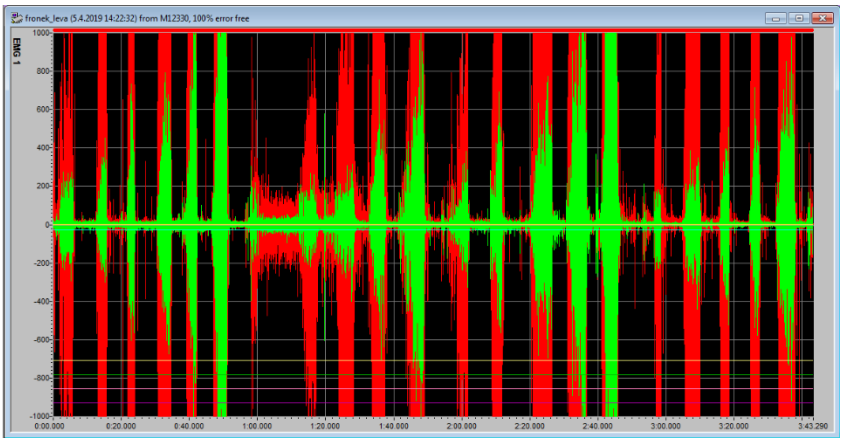

Fig. 5. Amplitude from Biometrics DataLog

The second, key for further work, is the data table generated from the program. The individual values of the electrical potentials measured by the electrodes are already recorded. Channel 1: EMG 1 for extensor electrode, Channel 2: EMG2

for flexor electrode. Also the first column of values belongs to EMG 1, the middle to EMG 2 and the last one is the list of values from the grounding electrode.
Output values from EMG 1 and EMG 2 are copied to MS Excel. The total number of values depends on the measurement length when reading 500 values per second. However, the number of values ranges from tens of thousands to hundreds of thousands. Holter offers only one frame per second accuracy, so the output is many times smaller. For further comparison with the values from Holter, it was necessary to reduce the values from DataLog to one frame per second. This was done in Excel. The values were numbered and converted into a positive form using the ABS absolute value function. Subsequently, every 500 values (one second of measurement) were averaged to one value that was filtered into a separate column. By supplying the measurement time from the first output block, a value table is generated from which an EMG curve graph can be generated for comparison with Holter. For each hand it was necessary to create 2 separate sheets with the procedure in Excel for values from EMG 1 and EMG 2. The output is 4 graphs, which were compared with outputs from Holter.
To compare the EMG chart from Excel, it was necessary to make sure that it was plotted in the same way as the potential amplitude plotted in Biometrics DataLog. Here it was more than obvious that the curve was drawn in the same way and it is relatively easy to estimate the boundaries of the individual positions and the presses performed. Therefore, the graph drawn in Excel was used for further comparison.
When the measurement is finished with the STOP button on the Holter, the data is stored in the internal memory of the connected computer. A window from its software is used to communicate with the instrument, where the test person data is specified. The saved data is then exported to MS Excel for further processing. Since more electrodes can be connected with Holter, the outputs are not split like DalaLog. The result is a comprehensive spreadsheet in MS Excel as well as a graph with data from both arms.

Fig. 6. Graph from EMG Holter Analyzer

The table shows the time by seconds and the EMG output data from each channel. EMG 1 (right extensor) and EMG 2 (right flexor), EMG 3 (left extensor) and EMG 4 (left flexor). The evaluation also marks the delimitation of individual positions by MARKER. Since the graph generated from Holter was directly compared with the graph generated from Excel from DataLog, there was no need to further modify these values.

5. Results

Holter graphs were compared with DataLog graphs generated in MS Excel. All measurements that were performed during the experiment were subjected to benchmarking.
A comparison of the waveforms showed that both instruments plot comparable EMG readings from the same measurement. However, comparing the plotted curves was the only way to compare the two instruments. It is not possible to compare specific values due to different units of both instruments - Biometrics DataLog measures in mV and Holter in Fmax. You can see some examples of compared graphs in figures below.

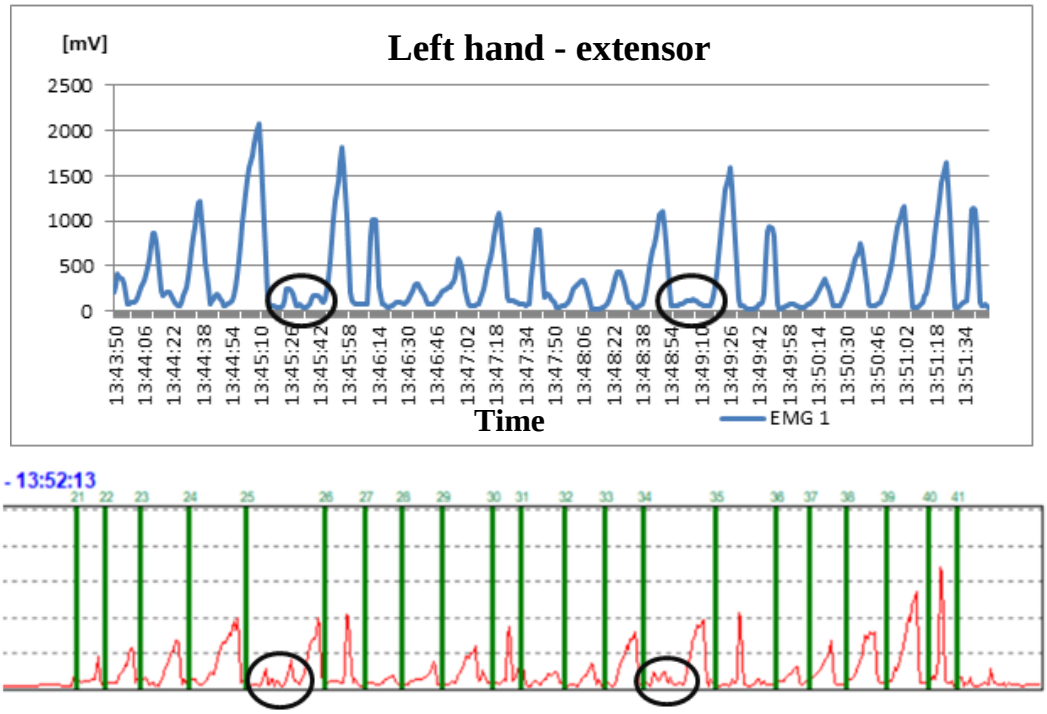

Fig. 7. Example of compared Graphs from DataLog and Holter – left hand extensor

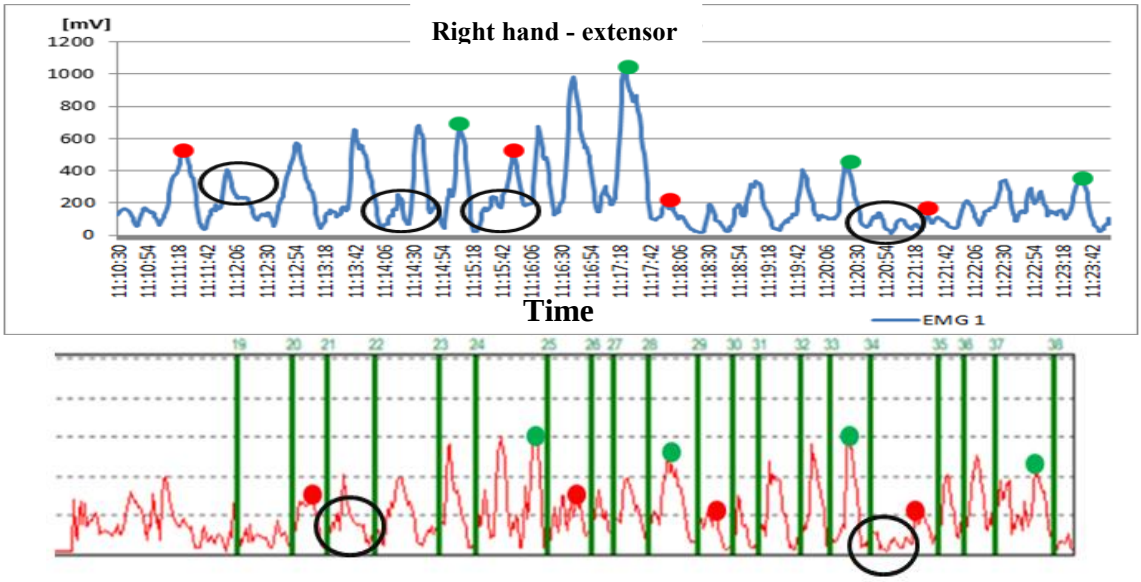

Fig. 8. Example of compared Graphs from DataLog and Holter – right hand extensor

EMG Holter from GETA is the only approved EMG sensor in the Czech Republic. The product has been operating on the Czech market for many years and due to zero competition there is no need to innovate and improve it. It focuses only on the methodology of local muscle load evaluation. As mentioned above, it measures in Fmax units and the output of this measurement is the percentage of load from Fmax, so there are no absolute values that can be further worked.
The work with both instruments is comparable, the big difference with selected instruments is that in the case of DataLog you can set the measurement accuracy.
The secondary output of the measurement was that, with increasing load, the electrical potential in the muscles increases. However, it should be noted that a sample of 20 test subjects is not sufficient for such conclusions and the results are not authoritative.

6. Conclusion

The aim of the study was to compare the outputs and measurement of two selected devices sensing electrical potential in loaded muscles of upper limbs. A partial goal was to evaluate the data. In conclusion, both instruments measure in a comparable way, the curves are plotted equally during the measurement, and the use of the instruments is not different

However, each of these devices has its own specific applications, which, however, cannot be compared due to different units. There was also another output of the research, the secondary output of the measurement was that with increasing load the electrical potential in the muscles increases.

7. Acknowledgments

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8. References

[1] Occupational diseases in the Czech Republic 2017, http://www.szu.cz/uploads/NZP/Hlaseni_NzP_2017.pdf
[2] Occupational diseases in the Czech Republic 2016, http://www.szu.cz/uploads/NRNP/aktual_Hlaseni_NzP_2016.pdf
[3] Mathiowetz V, Kashman N, Volland G, Weber K, Dowe M, Rogers S: Grip and pinch strength: normative data for adults. Arch Phys Med Rehabil 66: 69-72 (1985).Electromyography (EMG) My health. My Health - Mental and Physical Wellbeing [online]. 2001. Available from: https://www.mojezdravi.cz/vysetreni/elektromyografie-emg-1922.html
[5] EMG [online]. Available from: https://www.kntb.cz/emg
[6] Electromyography (EMG) - Vitalion.cz. Examinations - Examinations Database - Vitalion.cz [online]. Available from: https://vysetreni.vitalion.cz/elektromyografie/
[7] EMG Holter | Physiology of work. Home - User Manual Physiology of work [online]. Copyright © 2017. Available from: http://fyziologie.getacentrum.cz/ke-stazeni/
[8] JIRÁK, Zdeněk and Bohumil VAŠINA. Physiology and psychology of work. Ostrava: University of Ostrava, Faculty of Health Studies, 2009. ISBN 978-80-7368-610-9.
[9] Biometrics Ltd. [online] Available from: http://www.biometricsltd.com/about.htm