POSSIBILITIES OF DATA OBJECTIFICATION REACHED VIA AN ELECTROMYOGRAPHIC RECORD WHILE OUTDOOR ACTIVITIES OF CYCLIC NATURE

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Abstract
This study deals with an electromyographic method as a proper objectificational agent used to obtain and interpret data while outdoor activities of cyclic nature. The fundamental principle of this method is scanning of an electric responses of a muscle tissue through electrodes. These electrodes, stuck on a skin, scan potentials amount of a muscle fibers and thus provide a global information about the muscle function or at least its part. On one hand, this method seems to be essential for this type of motion, nevertheless on the other hand, it is necessary to follow certain fundamentals and principles which the study summarize. It is not also simple to interpret and draw any conclusions from number of data obtained by measuring. Our article advert to the above-mentioned issue either and it digestedly indicates possibilities of data evaluation within the frame of intraindividual and interindividual analysis and findings relating to a cyclic motions received while pursuit of an outdoor activity.

Key words:
Electromyography, cyclic motion, interindividual analysis, intraindividual analysis

Souhrn
Tato studie se zabývá problematikou elektromyografické metody jako vhodného objektivizačního prostředku k získávání a následné interpretaci dat při outdoorových aktivitách cyklického charakteru. Základním principem této metody je snímání elektrických projevů svalové tkáně pomocí elektrod, kdy povrchové elektrody přilepené na kůži snímají sumu potenciálů mnoha svalových vláken pod nimi a poskytují tak globální informaci o činnosti celého svalu nebo jeho podstatné části. Tato metoda se zdá být pro tento typ pohybu na jedné straně velmi ideální, avšak na straně druhé je třeba k získání validních dat dodržovat určité zásady a principy, které tato studie shrnuje a sumarizuje. Není také jednoduché z poměrně značného množství dat, které se měřením získají, následně přehledně interpretovat výsledky resp. vyvozovat určitá zjištění nebo závěry. Na tuto problematiku tento přehledový článek poukazuje také a přehledně uvádí možnosti vyhodnocení těchto dat v rámci intraindividuální i interindividuální analýzy a zjištění u cyklických pohybů získaných při provozování outdoorových aktivit.

Klíčová slova:
Elektromyografie, cyklický pohyb, interindiviuální analýza, intraindividuální analýza

Introduction

The method of the electromyographic record of muscle activity is currently understood as objectificational utensil while searching coordinating relations of the locomotor system. This method is known as the most exact and the most available method which is used for outdoor measuring of muscle activity in vivo. Many authors deal with the EMG method and its evaluation (DeLuca, 1997, 2001; Konrad, 2005; Hug, 2011; Pánek, Pavlů & Čemusová, 2009; DeLuca & Erimm 2001; Véle, 2006 and others).

"Surface electromyography is experimental technique which deals with development, recording and analysis of the myoelectric signals. The myoelectric signals are created by change of the muscle fibers membrane state." (Basmajian & DeLuca, 1985)

According to Kadaňka (Kadaňka, Bednařík, & Voháňka, S., 1994) the electromyography is: "Method of registration and study of spontaneous and voluntary electric muscle activity." Zedka (Zedka in. Kolář et al., 2009) reports: "Electromyography is an electromyographic method enabling adjudication of work or activation of skeletal muscles and its controlling by nervous system. Fundamental principle is to scan electric responses of the muscle tissue through electrodes which work as an antenna. Surface electrodes, stuck on a skin, scan potentials amount of a muscle fibers and thus provide a global information about the muscle function or at least its part."

EMG is used in various branches such as neurology, neurophysiology, physiotherapy, orthopedics, sport medicine, biomechanics, ergonomics, zoology etc. (Clarys, 2000). (Rodová, D., Mayer, M., & Janura, M., 2001) Electromyography method enables recording direct or indirect muscle and nerve excitability by means of surface electrodes (unipolar, bipolar, multi-electrodes i.e. bigger electrodes amount with minimal distance). Source of the electromyographic (further EMG signal) signal is change of the membrane potential which is followed by restitution on original value. Sequence of these changes (depolarization, repolarization) is displayed in EMG as action potential (AP) representing nervous agitation. Record of these summing potentials is called electromyogram (Keller, 1999). However, it is not simple summation of electric tension at particular moment, the result is interference in volume conductor (muscle, skin, electrodes), reports Rodová (Rodová, D., Mayer, M., & Janura, M., 2001).

The aim of our work is intervention of possibility to employ the EMG method and possibility of evaluation of obtained data relating to cyclic motions and its eventual usage in outdoor activities.

Methods

In this article we use especially retrospective and continuous literary recherché of texts dealing with the issue of surface electromyography and document analysis, particularly abroad scientific articles and publications (např DeLuca, 1997; Hug & Dorel, 2009; Konrad, 2005; foissac, M. J., Berthollet, R., Seux, J., Belli, A., & Millet, G. Y., 2008; Basmajian, J. V., & DeLuca C. J., 1985; Clarys, J. P., 2000; Day, S., 2002; Decker, M., 1999; Solnik, S., 2010; Stegeman, D. F., & Hermens, H. J., 1997), which solve fundamental procedures, methods, notifications and possible ways of the electromyographic signals evaluation- especially the cyclic nature. These possible ways of obtaining, assessing and adjudicating of the electromyographic signals and necessary procedures for intraindividual and interindividual adjudication are mentioned in the following chapter.

Findings and discussions

Spectral analysis generally makes for the signal description via its constituents in the frequency domain. Display of particular harmonic signal components is useful primarily for elimination of the spurious constituents and subsequent evaluation of the signal character (Jan, 2002). It is possible to describe the obtained signal in the time or frequency domain. So called transforms secure transition of explications from the time domain to the frequency domain. So called Fourier transform makes for often used function transformation from the time domain to the frequency domain. This transformation enables getting of the signal image which can be subsequently processed and analyzed (Šňorek 1999). However, it is necessary to select adequate methods to process the signal and follow certain rules while the data analyzing. Konrad (2005) gives certain categories in his publication which demand to be followed while the signal processing and analyzing. These categories are solved in the following chapter.

No. 1 Muscle activity

Even though this category is quite unambiguously definable, it should not be underestimated. The key while the EMG record analyzing we mainly focus on observation of the clues created by the muscle activity. In light of nominal level we can answer merely yes or not, i.e. muscle is active or not. Nevertheless, what about muscles which ensure apparatus stability? Basically, healthy muscles relax and contract only whether it is necessary. If muscle indicates constant activity even in sleep mode it can stand for active myospasm, joint instability, bad muscle coordination etc. Then it is necessary to take this findings into account in the analysis or even displace the participant from the experiment (Konrad, 2005). Compared to that Kračmar (2007) qualifies this muscle activity as postural muscle function.

No. 2 Is a muscle active as it should be?
There is not definite answer on the basis of obtained electromyogram. Once the variable amplitude through particular measurements is compared, it is necessary to realize so called data normalization, i.e. EMG conversion to the certain scale which is typical of all measurements. The timeline normalization makes for decrease of interindividual motion variability throughout the measurement. On the basis of timeline devolution to percent of work cycle, it is possible to compare observed activity even among individuals who carry out the motion with different time duration (Hug, 2011). Konrad (2005) reports that the timeline normalization is suitable especially for comparison of cyclic motions. Further he reports that these types of obtained data are rather ordinal than metric scale on which basis it is possible to determine the muscle participation. Based on these types of data we can state only definitions: the highest reached value of a muscle activity or test with the lowest activity etc.

No. 3 Is a muscle active and when not?
We can observe the muscle involvement due to the muscle timing within the framework of certain action in comparison to the others (order of "activation"). The timing may be calculated on the metric base of time submission as an ordinary software used for this type of data can do. Cyclic motions which repeat again and again such as walking are ideal for this type of data (Konrad, 2005).
Delay between EMG signal and force is different and it depends on various factors (according to DeLuca 1993):

- a) Muscle tissue composition
- b) Pace of motor units action
- c) Flexible features of muscles and tendons

More aerobic, slower and slowly defatigable muscle tissues have gradual onset of force in comparison with more glycolytic, faster and more defatigable muscle tissues. Muscles containing bigger amount of fast muscle tissues have shorter delay between EMG signal and produced force. This delay is oriented in hundreds of milliseconds (DeLuca, 1997).
Compared to this Hug (2011) affirms that every attempt at precise time estimation, when a muscle starts and ends its activation, meets a difficulty which can not be entirely solved by current knowledge and it demands further studies. According to him, under the investigation, it is important to focus on a muscle coordination while performing the motion. The muscle coordination is defined as the muscle activity distribution or the force distribution among the particular muscles in order to produce certain motions combination within joints (Hug, 2011).

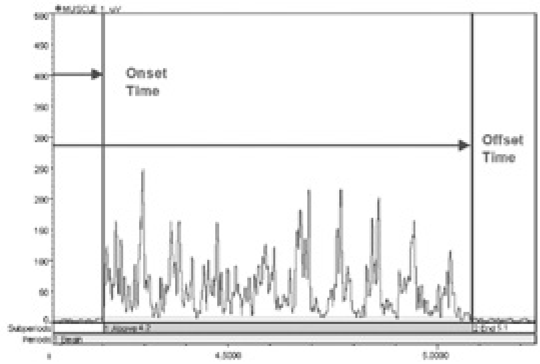


Figure 1: Muscle activation and deactivation while overrun of selected threshold (Konrad, 2005)

It is important to filter out the signal for analysis of a muscle contractions. DeLuca (1997) states that the beginning of a muscle activation is denominated as a value of two standard deviations from the average value of a signal. Provided this value is positive or negative for a certain time period (about 20 milliseconds) it can be qualified as a muscle activation or deactivation. See in figure 1 (Konrad, 2005). Hug & Dorel (2009) and Konrad (2005) recommend another method appointing particular activating threshold. Values of this threshold reach third standard deviation from the quiescent condition. Similar result can be obtained if threshold values are adjusted at 15-25% of the maximal signal amplitude. Hug (2011) point out that the identification of a muscle activation can be illegible, litigious and dependent on threshold selection.
While analyzing two same muscles doing different exercises when the curves are similar (especially cyclic motions, e.g. Nordic walking), we can use cross-correlation of the curves to establish the time shift. This time shift can be theoretically denomina-

ted as a time of muscle activation or deactivation (Hug & Dorel, 2009; Hug, 2011). The cross-correlations among muscles and adjudication of its antagonistic and synergistic relations were studied by DeLuca & Erim (2001).

Špulák (2012) states that the most precise method of present is so called method of “triangular” detection, which is used for analysis of the EMG curves. This method can best determine the moment when a muscle starts and ends its activation. Connection of tmin and tmax is created in certain segment from the obtained values, see in figure 2. This abscissa is linked with a point from curve of the signal continuance where the detected triangle reaches the biggest area. The point of a muscle activation ton lies under this join. This relative onset (ton) is calculated within each segment and consequently, on the basis of interpolation, it is integrated into standard length and average is made. The same procedure is conducted for the detection of deactivation (t_{off}).

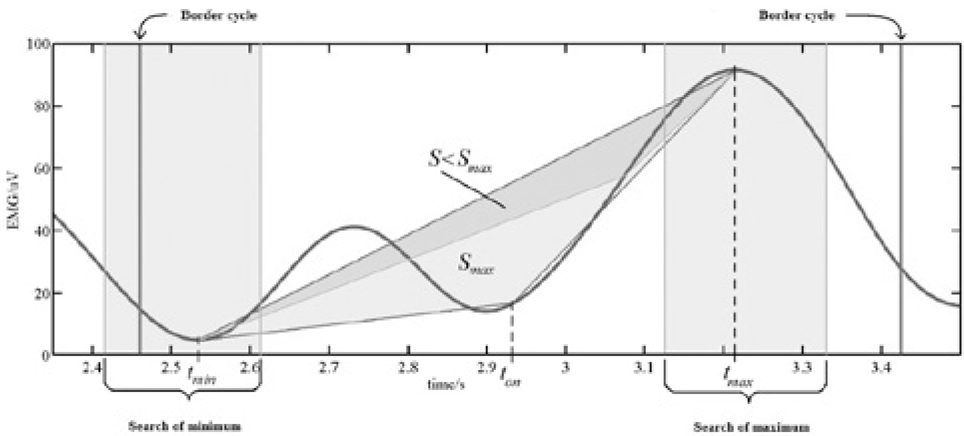
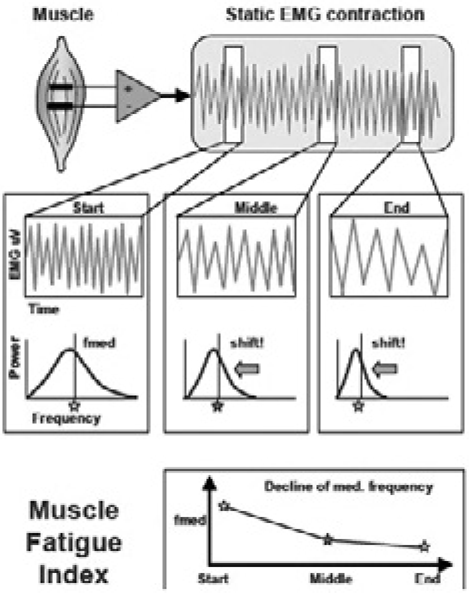


Figure 2: Finding of muscle activation based on the triangular detection of one motion cycle (Špulák et al., 2012)

No. 4 The rate of a muscle participation?
Based on found microvolts, there is not straight answer. On one hand there are opinions that the EMG amplitude is not quite suitable for interindividual comparison or long interval observation because the muscle activity and muscle force can be affected by numbers of exterior parameters. Hence, it is possible to compare the microvolts values only as a conversion to certain percents and determine some conclusions from the obtained values very warily. This quantity pattern of evaluation may be used only while comparison of the same muscles, provided that no electrodes were overlapped during the particular measurements (Konrad, 2005). On the other hand there are also opinions that it is possible to draw certain conclusions based on the obtained amplitudes. Zedka (Zedka & Kolář, 2009) reports:
“It is possible to establish the force developed by a muscle contraction from the surface EMG. The effort to use EMG signal comes from the finding that EMG amplitude is proportional to force performed by particular muscle. Due to good knowledge of the issue we can fairly precisely determine e.g. relative contribution of a certain muscles to general torque that functions in articulation of two corporal segments.” Konrad (2005) reports that conclusions may be determined only on the basis of conversion to certain percents on the other hand he describes parameters that are suitable for processing of EMG signal characteristic which may be processed on the basis of Fourier transform - it is a mathematic method which allows analysis of a signal process and its conversion to sum of a sinus signals proper frequencies and amplitudes (Psohlavec, 2001). According to this author, fundamental characteristics that may be further studied are especially maximal curve values, diameter and median which divides the created area under the curve into same halves. Thus we can see that there are many different attitudes to processing of the EMG results. Probably the best method for comparing the size of the area under the curve is to relate this area to certain standardized referential value preferably to the maximum voluntary contraction as many authors recommend (Pánek, 2011; Konrad, 2005; Hug & Dorell, 2009; Hug, 2011; DeLuca, 2001).

No.5 Is the observed muscle tired?
In the framework of this point it is important to emphasize that the proband can get tired during the measurement which can influence measured values (Basmajian & DeLuca, 1985; DeLuca, 1997). In the following picture 3 (Konrad, 2010) see the obvious values change due to time increase.



Picture 1: The scheme of possible effect on EMG signal on the basis of muscle fatigue (DeLuca, 1997)

The measurement and the subsequent analysis of the enter data should be conducted on the basis of the aforesaid categories and always, at least on two involved muscles or each muscle of the entire muscle chain (Konrad, 2005).
The data normalization is realized on the basis of signal amplitude. Due to this fact it is far easier to establish activation or deactivation of a muscle. It is necessary to detect particular muscle separately as well as realize seubsequent data evaluation and amplitude rearrangement to formulate the values of the maximum voluntary contraction (MVC). For examination of a particular muscle it is important to constrain a joint affecting motion which may inhibit from maximal muscle extension against static resistance. Each muscle is measured separately after the warm up. To avoid muscle exhaustion it is recommended to realize the exercise maximally twice or three times with the contraction length shorter than five seconds.

For the muscle recovery at least thirty seconds between particular contractions should be kept. Afterwards we can record the highest possible maximum voluntary contraction (Konrad, 2005; DeLuca, 1997). Some publications state that while subsequent measuring we may obtain higher muscle values than its measured MVC. Voss (1985) reports that this trend may appear especially in connection with the big muscle groups while cyclic motions. Hug (2011) considers this finding as a mistake while putting up a resistance, even so he says that it is possible to relate a muscle activation to the MVC. DeLuca (1997) recommends to take the submaximal values while the amplitude normalization and qualify the proper referential point to the 80% of MVC because the force and the EMG values do not have to be quite stable over this threshold value. Thus most of the authors recommend to use relation to the submaximal or the maximum voluntary contraction. The MVC values under 10% are considered as an inadequate muscle activation to be analyzed (Hug & Dorel, 2009). Compared to that, values over this MVC border of particular muscle are adequate to detection of the functional capacity of a certain muscle motor units (Benešová et al., 2011). Decker (1999) introduces various types of muscle activation: minimal activation up to 20% of MVC, middle activation 21-50% of MVC, expressive muscle activation over 50% of MVC.
The method of EMG is understood as an objectificational utensil while searching coordinating relations of the locomotor system. This method is, over all above-mentioned deficits, known as the most exact and the most available method that is used for outdoor measuring of muscle activity in vivo. Nevertheless it is needed to understand that the obtained EMG data are rather as a probabilistic values which depend on two levels of estimation. It is possible to detect the values necessary for subsequent detection of the muscle activation from the size of the area under the curve. From the detection of the muscle activation we can deduce the performance. Even though this probabilistic method is not able to formulate the size of the needful measurement error, currently it is the only method which is able to objectify the performance of the locomotor system under outdoor conditions outside the laboratory. On the basis of the above-mentioned findings regarding the electromyographic detection of a muscle activity, many authors (e.g. Solnik et al., 2010; Day, 2002; Stegeman & Hermens, 1997; Windhorst & Johansson, 1999) refer to procedures recommended by SENIAM.

Recommendations according to the SENIAM:

- It is necessary to use an electrode of one particular size. The reason is to eliminate signal failures which may be caused by distinct entry impedance.
- The size must be modified so that the demanded number of motor units could be recorded (c. 10mm) and to avoid spurious crosstalk.
- Do not conduct the measurement close to an electric installation or within a noisy surrounding.
- Measuring bigger fascicles, the distance between the electrodes centers must not be bigger than 20mm. Measuring smaller muscles, the distance should not get over the quarter length of the measured muscle.
- The electrodes material must have low resistance and constancy. Material from Ag and AgCl is recommended. Electrolytic gels and creams decrease the rate of the skin resistance.
- The electrodes should be from light material and the cables, transferring electric potential from these electrodes, should be fixed by an elastic tape to restrain from changes of the amplitude sizes of the consequent EMG curve.
- A suitable place for installation of the electrodes on a muscle is defined as a position of two bipolar locations overlapping a muscle in relation to the line of two anatomic points. The aim is to localize place of a muscle where we can record the demanded signal as good as possible. Particular electrodes must be stuck in a muscle fibers direction, otherwise it can lead to drop of the amplitude values by 50%.
- It is needful to clean, degrease and eventually shave the place intended for installation of the electrodes.
- Due to elimination of a muscle fatigue it is necessary to not overload the individual by excessively long physical activity or muscle contraction.

Within the framework of comparison of particular muscles while realizing different motions, overlapping of the electrodes must not happen during the data acquisition.

The signal analysis and subsequent assessment while cyclic motion within the time domain can be described as a function which indicates dependence of signal immediate deflection on time. Rough record of the motion process with the sampling frequency 1000Hz demands to be rectified and transferred to absolute values (Konrad, 2005). From the modified signal, we choose ten consecutive step phases (e.g. 10th-20th step) which we use for enumeration of the basis value regarding an average step cycle and which we can subsequently use for intraindividual comparison of a muscle activity while Nordic walking and walking (see figure 3).

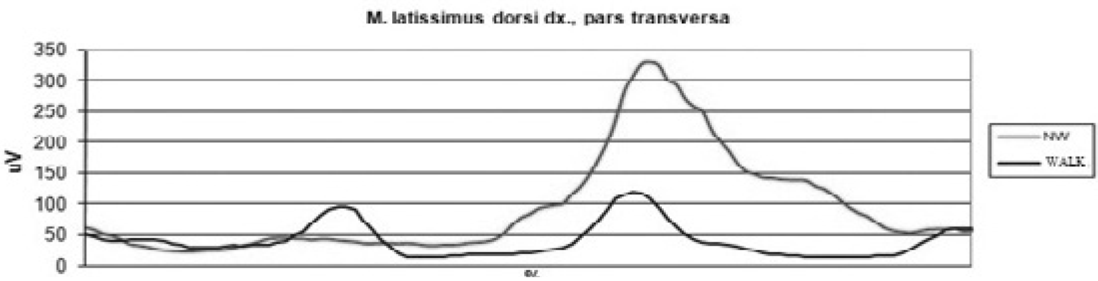


Figure 3: The EMG signal process of a chosen muscle of average step cycle while various types of locomotion (Škopek, 2012

It is possible to use so called triangular detection of activation onset and offset (graph 2) for determination of the time lag of muscle activation onset with subsequent intraindividual and interindividual analysis of chosen section. The triangular detection is currently used as the most exact method (Špulák, 2012).

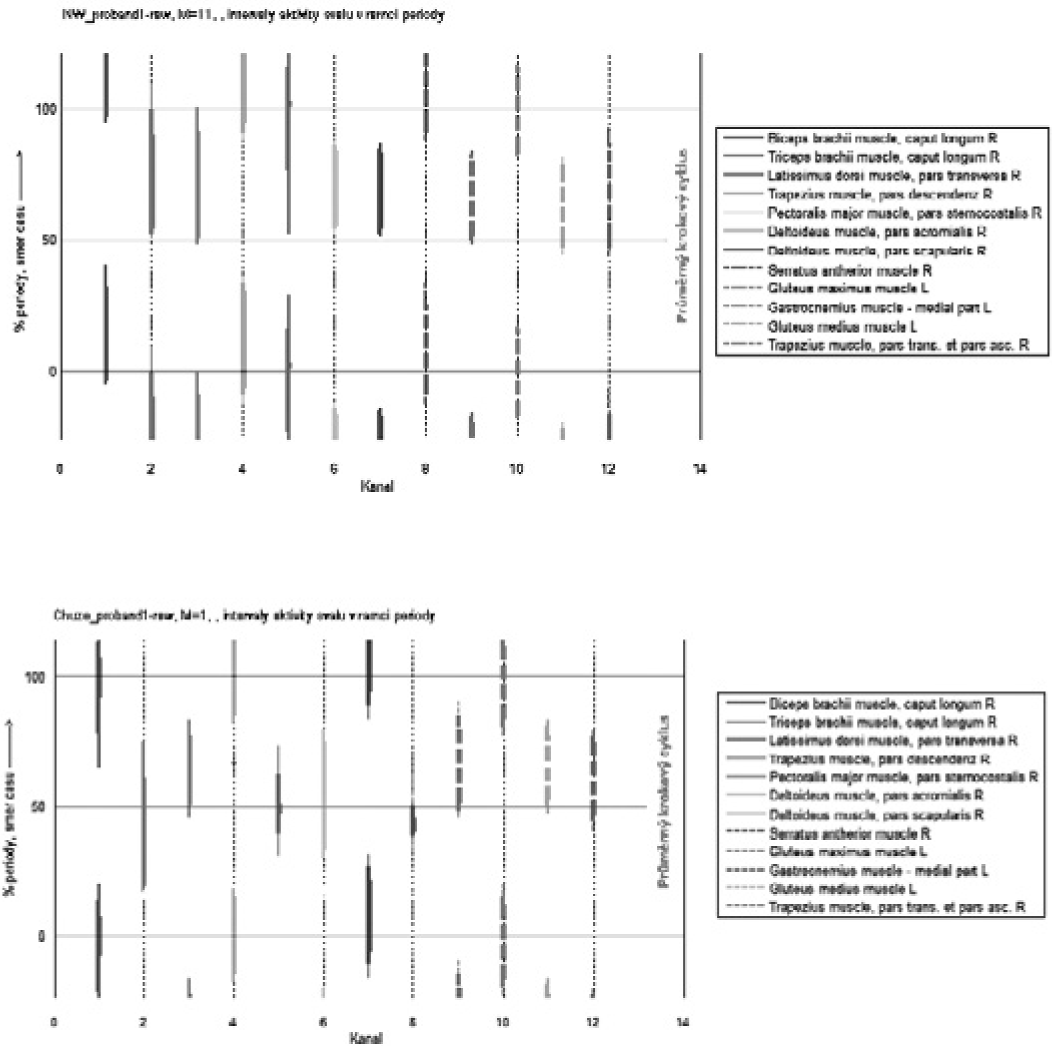


Figure 4: Intervals of a muscle activity within the frame of period while Nordic walking and walking

The values of muscle participation are detected via scripts editor in programming environment Matlab (version 7.8.0, R2009 a). Rough digital EMG signal needs to be entirely rectified through low--pass filter (cot off frequency 3.6 Hz, FIR order 501). Particular motion segments should be subsequently reconnoitre for retrieval of the phases minimum. Provided that during the cycle more minimum values would be found, repeat the procedure for the selected cycle part to find the main minimum. As regards the maximum values, you can follow the same process. Most authors (DeLuca, 1997; Hug &Dorel, 2009; Konrad, 2005; Foissac et al., 2008) recommend to normalize the timeline to percents for better comparison among the participants and due to different length of the motion lasting. See the data display of activation in figure 4.

The intraindividual comparative analysis is also possible on the basis of modified correlation function of two signals as Hojka recommends (Hojka, V., Vystrčilová, M., & Kračmar, B., 2010) with subsequent evaluation of similarity of muscles couples activation based on the Spearman correlation coefficient (chart 1).

Proband 1												
Proband 1 NW	M.biceps brachii dx.	M. triceps brachii dx.	M. lat. dorsi dx. , p. tran-sversa	M.trapezius dx., p. desc.	M. pectoralis maj., dx.	M. deltoideus p. acromialis, dx.	Deltoideus p. scapularis, dx.	M. seratus ant., dx.	M.gluteus max., sin.	M.gastrocne-mius, sin.	M. gluteus med., sin.	M. trapezius p. asc., dx.
M.biceps brachii dx.	1	-0,188	-0,140	0,518	-0,08	0,038	-0,045	0,427	-0,036	0,286	-0,015	-0,083
M. treceps brachii dx.	0,188	1	0,745	-0,406	0,39	0,601	0,762	0,075	0,513	-0,126	0,524	0,685
M. lat. dorsi dx. , p. transversa	0,140	-0,745	1	-0,336	0,439	0,6	0,817	0,157	0,768	-0,197	0,776	0,848
M.trapezius dx., p. desc.	-0,518	0,406	0,336	1	-0,12	-0,106	-0,247	0,354	-0,149	0,492	-0,112	-0,216
M. pectoralis maj., dx.	0,08	-0,39	-0,439	0,12	1	0,238	0,366	0,242	0,429	-0,131	0,449	0,45
M. deltoideus p. acromialis, dx.	-0,038	-0,601	-0,6	0,106	-0,238	1	0,784	0,118	0,453	-0,032	0,488	0,563
M. deltoideus p. scapularis, dx.	0,045	-0,762	-0,817	0,247	-0,366	-0,784	1	0,123	0,68	-0,096	0,682	0,777
M. seratus ant., dx.	-0,427	-0,075	-0,157	-0,354	-0,242	-0,118	-0,123	1	0,197	0,404	0,265	0,249
M.gluteus max., sin.	0,036	-0,513	-0,768	0,149	-0,429	-0,453	0,68	-0,197	1	-0,207	0,838	0,758
M.gastrocnemi-us, sin.	-0,286	0,126	0,197	0,492	0,131	0,032	0,096	-0,404	0,207	1	-0,079	-0,107
M. gluteus med., sin.	0,015	-0,524	-0,776	0,112	-0,449	-0,488	-0,682	-0,265	-0,838	0,079	1	0,748
M. trapezius p. asc., dx.	0,083	-0,685	-0,848	0,216	-0,45	-0,563	-0,777	-0,249	-0,758	0,107	-0,748	1

From the above-mentioned results it is possible to search for specific trends in the individual muscles activation. We can observe whether the similar activation happens or not within the frame of whole group of observed individuals. Especially correlation values which reach the value over 0.7 (red numbers in the table 1) should be observed. These muscles can be consequently indicated as muscles with high association rate (Hendl, 2004). Certainly it is necessary to take into consideration its placement and its function and only then we can discuss its co-operation or co-activation.

The interindividual comparative data analysis is possible on the basis of obtained values of the area under the curve in case that the electrodes were not overlapped during particular experiments. This evaluation can be realized from values of the particular muscles activation or, if you like, microvolt devolution to percents and referring to MVC of particular muscles (DeLuca, 1997; Hug & Dorel, 2009). Observed parameter can be the value of the area median under the curve which can be analyzed from 3sec interval of steady-state isometric contraction (Konrad, 2005; Pánek, 2011). Consequently, it is possible to observe the distinction of the particular muscles activation formulated in percents with subsequent correlation to referential value. Due to Wilcoxon test of dependent samples we can observe its statistical relevance in the frame of interindividual comparison of different locomotion types at selected muscles (e.g. Nordic walking or walking) and then the established values can be transferred to figure 5 (Hendl, 2004).

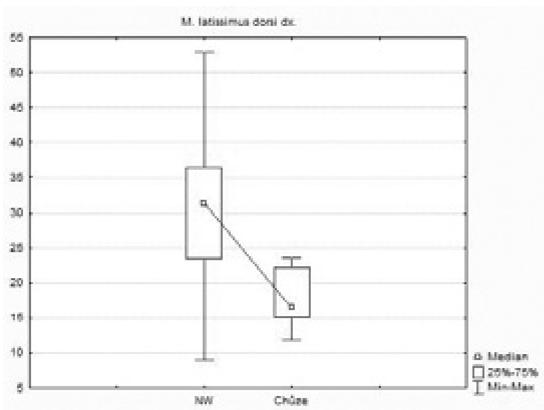


Figure 5: Box graph of the selected muscle obtained on the basis of the Wilcoxon test

Human singularity is the next factor that needs to be impeached while processing the EMG findings. There are not two absolutely same people. Hence, we can not expect the same findings while the muscle activity behavior not even in case of walking which is one of the fundamentals motions (DeLuca, 1997; Hug & Dorel, 2009; Konrad, 2005 etc.).

Conclusions

The aim of this article is to summarize and solve the issue of evaluation and data acquisition due to scanning of the electromyographic signals while cyclic nature activities. The article also emphasizes frequent problems which may appear while not following the proper rules and thus subsequent data distortion, using the surface EMG, may happen. Following facts result from the above-mentioned findings:

1. The EMG method can be recommended for scanning of a muscles activities while cyclic nature motions at outdoor activities such as walking, Nordic walking, cycling, running, ski running, skiing, ski touring, Nordic running, Nordic blading, kayak, sea kayak, etc., however, it is needed to follow aforesaid principles not only during the measurement but also during the data acquisition.
2. In the subsequent interpretation of the findings resulting from the obtained data, it should be noted that despite compliance with all the principles, it is necessary to be provident while stating the conclusions. Thus, we rather want to find some similarities or trends among participants in the muscles activity behavior which leads to further findings.

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