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Original paper

The effect of the fatty tissue on EMG signal in young women

PAWEŁ BARTUZI*, TOMASZ TOKARSKI, DANUTA ROMAN-LIU

Central Institute for Labour Protection-National Research Institute, Warsaw, Poland.

The aim of this study was to investigate the influence of fatty tissue layer on EMG signal parameters as a function of force level and type of muscle in young women. On the basis of body mass index (BMI) and the amount of fatty tissue (FT) 30 young women were divided into two equal groups: obese (O) and reference group (R). The EMG signal was measured on 5 levels of load from 2 muscles: *palmaris longus* (*PL*) and *rectus abdominis* (*RA*). The EMG signal parameters (RMS and MPF) were analysed. The results of the study suggest that the EMG signal is sensitive to fatty tissue layer. However, the influence of fatty tissue layer on the EMG signal is dependent on the muscle examined. The analysis of the dependence of the EMG signal on fatty tissue layer based on more detailed parameters of the power spectrum is desirable.

Key words: *EMG, fatty tissue, muscle load*

1. Introduction

Excessive muscle load and fatigue during work may lead to disorders of the musculoskeletal system [1], [2]. This means that limiting fatigue under the occupational conditions may result in a decrease in the number of complaints associated with the dysfunctions of musculoskeletal system. Therefore, it is crucial to assess the load and fatigue properly, which can be done with the application of non-invasive surface electromyography (EMG) [3]–[5]. Muscle load and fatigue may be assessed based on the changes in the values of parameters which characterise EMG signal registered while performing muscular activities [6]–[11]. In order to estimate the muscle load during performing various activities, the analysis of EMG signal amplitude is carried out. A great number of studies indicate the relationship between the EMG signal amplitude and the force developed by muscles [12]–[14]. For muscle fatigue analysis, apart from time domain analysis (amplitude of EMG signal), a frequency domain is explored as well [4], [6], [8]. Power spectrum of EMG signal is mostly expressed by such parameters as *median frequency* (MF) and *mean power frequency* (MPF).

In order to assess the load and fatigue properly, many factors should be taken into consideration. One of such factors is subcutaneous layer [15], [16]. Fatty tissue layer between the electrode and the muscle can be the cause of inaccuracy in the results of the measurement obtained with the application of surface electromyography [17], [18]. A study [15] indicates that an increase in fatty tissue layer causes a decrease in the values of EMG signal amplitude and an increase in the cross-talk in muscles adjacent to activated muscle [15]. On the other hand, FARINA and RAINOLDI [16] suggest that the subcutaneous tissue layers attenuate the potential distribution present at the muscle surface.

Previous studies aimed at investigating the influence of fatty tissue layer on the characteristics of the EMG signal. They showed the effect of fatty tissue thickness on the parameters of the EMG signal analysed in the time domain, i.e. the amplitude of the signal [15], [16]. However, there are no studies

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* Corresponding author: Paweł Bartuzi, Central Institute for Labour Protection-National Research Institute, Czerniakowska 16, 00-701 Warsaw, Poland. Tel.: +48 22 623 43 81, e-mail: pabar@ciop.pl

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showing the influence of subcutaneous layer on the parameters describing the power spectrum of the EMG signal, such as MPF, which are commonly used in the analysis of muscle fatigue.

The analysis of the EMG signal taking into account the thickness of the subcutaneous layer will allow us to determine the effect of fatty tissue layer on the amplitude of the EMG signal and also on the parameters of the power spectrum, so it will be possible to determine the effect of fatty tissue not only on the accuracy of muscle load assessment but also on the accuracy of muscle fatigue assessment.

The aim of this study was to investigate the influence of the fatty tissue layer on EMG parameters, which characterise the signal with time and a frequency domain, taking into account the force and type of muscle in young women. The results of this study provide us with information regarding muscles' sensitivity to disturbances caused by fatty tissue when obese population is considered.

2. Methods

2.1. Subjects

The research on 30 young women (mean age: 23 years, standard deviation: 3 years) was performed. The participants were divided into two equal groups: obese group (O) with BMI ranging from 27 to 34 and the level of fatty tissue (FT) above 31% as well as reference group (R) with BMI ranging from 18 to 22 and the level of FT up to 25%.

2.2. The muscles examined

During measurements the participants activated the forearm muscle *palmaris longus* (*PL*) and back muscle *rectus abdominis* (*RA*) with constant force and under isometric conditions (constant length of the muscles tested) which means the same load distribution in the muscles.

2.3. Protocol

The measurement for one person took about two hours in the morning. The subjects were informed about the experiment earlier and asked to come refreshed. The study was divided into four stages.

In the first stage of the study, the body weight and the body height of the subjects were measured and then, on the basis of these values, the Body Mass Index (BMI) was determined.

In the second stage, the percentage of body fat was measured using Futrex 6100 device. The measurement of body fat was made on the *biceps brachii* muscle. According to the producer of the Futrex device, the measurement of body fat on the *biceps brachii* muscle can approximate the whole body fat layer.


a) b)

Fig. 1. Body posture maintained during EMG signal measurements from: a) *palmaris longus* (*PL*) muscle, b) *rectus abdominis* (*RA*) muscle

In the third stage, the measurements at a maximum voluntary contraction (MVC) of the muscle tested were carried out. During these tests the external force, developed by the subjects, as well as the EMG signal, generated by the muscles as a result of external force, were registered. Muscle *PL* was activated by handgrip forces, whereas muscle *RA* by bending in the hip joint. Body postures maintained during the EMG signal measurements from *PL* and *RA* muscles are presented in figure 1.

In the fourth stage, five measurements for each muscle were performed, which creates 10 measurements for one person. The subject tested maintained the constant value of force on the level of 5%, 15%, 30%, 50% and 70% MVC. The orders of various measurements were different and determined on the basis of the tables of random numbers. Measurements were performed during determined time intervals. The EMG signal measurement at each muscle contraction level

(5%, 15%, 30%, 50% and 70% MVC) lasted 30 seconds, and 3-minute time intervals were kept between the beginnings of subsequent measurements. The measurements in following stages of the study are presented schematically in figure 2.

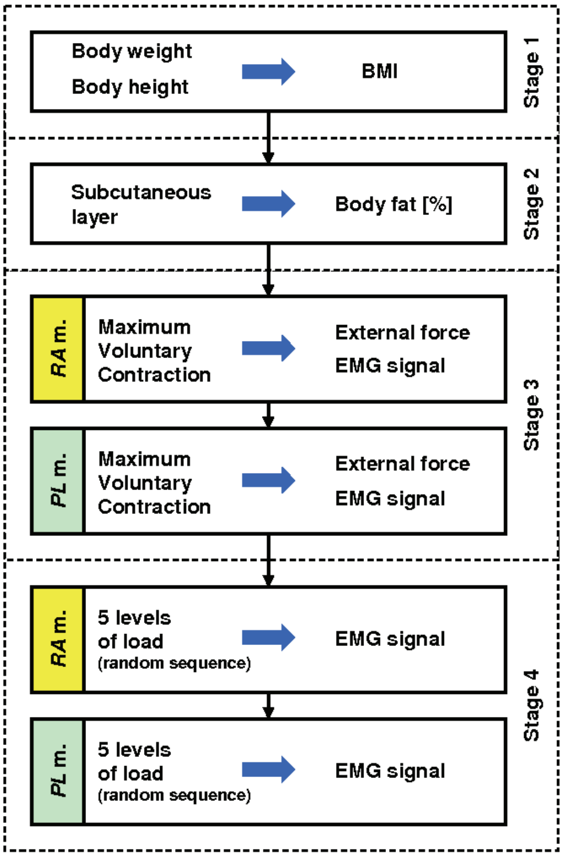

Fig. 2. The measurements in following stages of the study

2.4. Equipment

2.4.1. EMG measurement

For the measurements and registration of the raw EMG signal the Bagnoli-16 device (Delsys, USA) was used. Bagnoli-16 combined with a computer enables observation and recording of the raw signal. The EMG signal was registered with the usage of software EMG Works 3.5. The EMG signal was sampled at the frequency of 4 kHz. Bandwidth of Bagnoli-16 ranges from 20 to 450 Hz. The EMG signal was recorded with surface electrodes. Before the electrodes were stuck, the skin had been cleaned and disinfected with alcohol.

2.4.2. Fatty tissue measurement

The amount of FT was measured with body composition analyzer (Futrex 6100, USA), which provides a direct measurement of percent of body fat. This device enables measuring body fat using safe, near-infrared light to measure percent of body fat. The light absorption is measured to determine body fat.

2.4.3. Force measurement

A dynamometer, which together with an appropriate transducer allows us to change the applied force into an electric signal and then to display the force changes on a chart, was used to measure force. The software CPSv_2.0 (Characteristic of Force Course) was used to visualise and measure the force. The subject was able to see the real-time value of plotted force and the level of required force on the monitor. Consequently, it was possible to maintain the muscle force on a constant level.

2.5. Analysis

The analysis aimed at determining the effect of the fatty tissue layer and the force on the values of the EMG signal parameters from *PL* and *RA* muscles was carried out.

The RMS (root mean square) amplitude and the MPF (mean power frequency) determined on the basis of the power spectrum of the EMG signal were analysed. The parameter RMS expresses relative value obtained as a result of dividing the EMG signal amplitude obtained during measurements at each force level (5%, 15%, 30%, 50% and 70% MVC) by the value of the amplitude from measurement at the maximum voluntary contraction.

In order to determine the effect of the fatty tissue layer and the force on the values of the EMG signal parameters (RMS and MPF) from *PL* and *RA* muscles, the analysis of variance was performed. For a detailed examination of the differences between the levels of load, a post-hoc analysis was carried out using the NIR Fisher test. For statistical analysis the Statistica package, version 6.0, was applied.

3. Results

The marginal means and confidence intervals for RMS parameter from *PL* muscle for O and R groups during muscle tension at the 5 levels of load (5%, 15%, 30%, 50% and 70% MVC) are presented in figure 3, and the marginal means and confidence intervals for RMS parameter from *RA* muscle are pre-

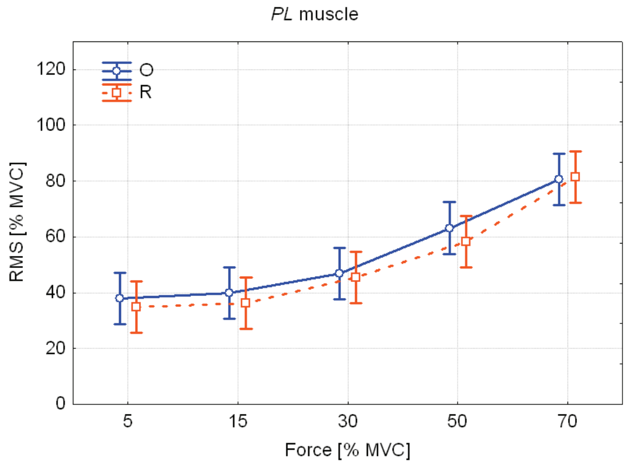

Fig. 3. The mean values and 95% confidence intervals for RMS (root mean square) parameter from *palmaris longus* (*PL*) muscle for O (obese) and R (reference) groups during muscle tension at 5 levels of load (5, 15, 30, 50 and 70% MVC)

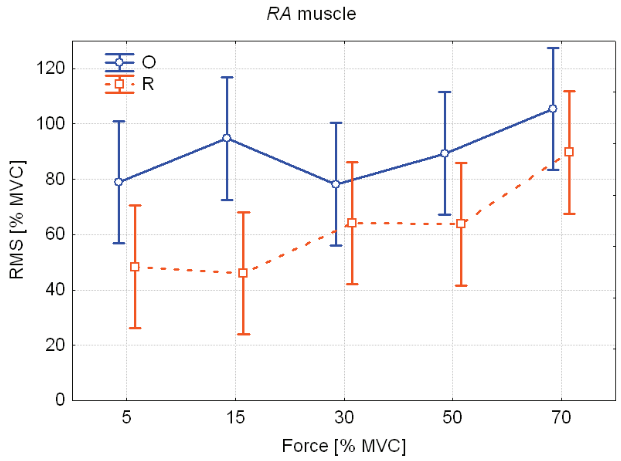

Fig. 4. The mean values and 95% confidence intervals for RMS (root mean square) parameter from *rectus abdominis* (*RA*) muscle for O (obese) and R (reference) groups during muscle tension at 5 levels of load (5, 15, 30, 50 and 70% MVC)

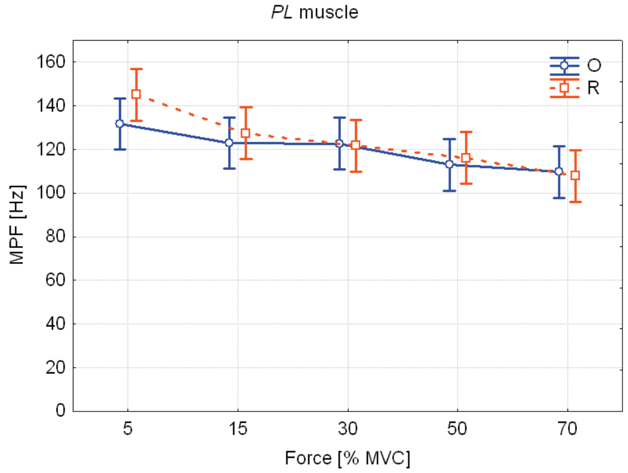

Fig. 5. The mean values and 95% confidence intervals for MPF (mean power frequency) parameter from *palmaris longus* (*PL*) muscle for O (obese) and R (reference) groups during muscle tension at 5 levels of load (5, 15, 30, 50 and 70% MVC)

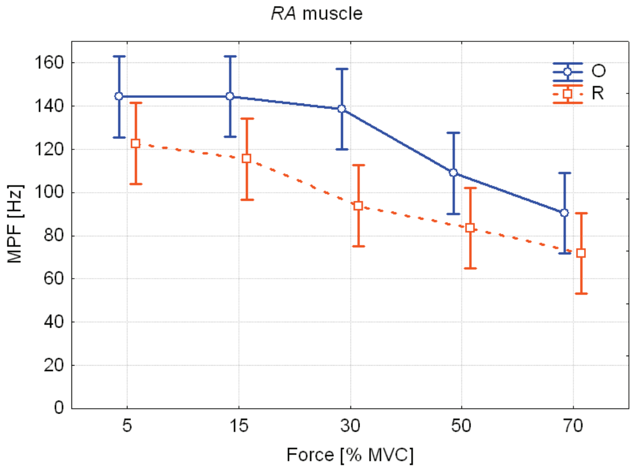

Fig. 6. The mean values and 95% confidence intervals for MPF (mean power frequency) parameter from *rectus abdominis* (*RA*) muscle for O (obese) and R (reference) groups during muscle tension at 5 levels of load (5, 15, 30, 50 and 70% MVC)

sented in figure 4. Figure 5 shows the marginal means and confidence intervals for MPF parameter from *PL* muscle for O and R groups during muscle tension at the 5 levels of load, while figure 6 depicts the marginal means and confidence intervals for MPF parameter from *RA* muscle.

Table 1 presents the effect of the fatty tissue layer (O – obese group and R – reference group) and the force level on the values of the RMS and MPF parameters from *PL* (*palmaris longus*) and *RA* (*rectus abdominis*) muscles. The results were obtained with ANOVA application. Tables from 2 to 5 gather the results of a post-hoc analysis for different levels of load carried out using the NIR Fisher test for the values of the RMS and MPF parameters from *PL* and *RA* muscles.

Table 1. The effect of the fatty tissue layer (O – obese group and R – reference group) and the force (5, 15, 30, 50 and 70% MVC) on the values of the RMS (root mean square) and MPF (mean power frequency) parameters from *PL* (*palmaris longus*) and *RA* (*rectus abdominis*) muscles, obtained by ANOVA application

Muscle	Parameter	Fat layer		Force	
		F	*p*	F	*p*
PL	RMS MPF	0.65 0.93	0.4214 0.3364	**31.94** **7.21**	**0.0001** **0.0001**
RA	RMS MPF	**14.54** **21.85**	**0.0002** **0.0001**	**2.71** **11.25**	**0.0326** **0.0001**

Table 2. The results of a post-hoc analysis for different levels of load carried out using the NIR Fisher test for the values of the RMS parameter from *PL* muscle

MVC (%)	15	30	50	70
5	0.7145	**0.0367**	**0.0001**	**0.0001**
15		0.0835	**0.0001**	**0.0001**
30			**0.0021**	**0.0001**
50				**0.0001**

Table 3. The results of a post-hoc analysis for different levels of load carried out using the NIR Fisher test for the values of the MPF parameter from *PL* muscle

MVC (%)	15	30	50	70
5	**0.0288**	**0.0074**	**0.0001**	**0.0001**
15		0.6107	0.0740	**0.0062**
30			0.1993	**0.0250**
50				0.3309

Table 4. The results of a post-hoc analysis for different levels of load carried out using the NIR Fisher test for the values of the RMS parameter from *RA* muscle

MVC (%)	15	30	50	70
5	0.5476	0.4991	0.2484	**0.0028**
15		0.9404	0.5789	**0.0158**
30			0.6309	**0.0193**
50				0.0614

Table 5. The results of a post-hoc analysis for different levels of load carried out using the NIR Fisher test for the values of the MPF parameter from *RA* muscle

MVC (%)	15	30	50	70
5	0.7088	0.0695	**0.0001**	**0.0001**
15		0.1479	**0.0004**	**0.0001**
30			**0.0353**	**0.0003**
50				0.1135

Based on the results given in tables 2–5 it can be stated that there are statistically significant differences in the values of the RMS and MPF parameters between the levels of force in both muscles analysed.

The higher number of differences between the levels of forces were noticed for the RMS parameter calculated for *PL* muscle. The fewest statistically significant differences resulting from the force level were observed in the values of the RMS parameter calculated for *RA* muscle, which may indicate that the fatty tissue in this muscle significantly affects the values of the RMS parameter.

4. Discussion

On the basis of figure 3 it can be inferred that with an increasing force the values of RMS parameter calculated from EMG signal registered from *PL* muscle also increase in both analysed groups (O and R). The values of RMS parameter are similar in both groups (O and R) in *PL* muscle. In the case of RMS parameter calculated from *RA* muscle presented in figure 4, in O group an increase in the values at the force level above 30% MVC is visible. There are also visible the differences in the values of this parameter between groups (O and R).

Figure 5 shows that the values of MPF parameter are similar in both groups (O and R) in *PL* muscle, while in RA muscle (figure 6) the differences between groups in the values of this parameter are visible.

The results of the analysis indicate that contraction level influences the EMG signal parameters in both muscles, whereas the fat layer affects the values of RMS and MPF parameters only in *RA* muscle. In *PL* muscle, there was no influence of fatty tissue layer on the parameters analysed. In the case of *PL* muscle, the effect of the developed force on the values of the EMG signal parameters in both groups is visible in most of the cases analysed, while in the *RA* muscle unambiguous changes caused by the force of parameters RMS and MPF are visible above 30% MVC. Also the data gathered in tables 2–5 prove that the fewest statistically significant differences resulting from the force level were noticed in the values of the RMS parameter calculated from *RA* muscle. These relationships may suggest that taking into account the impact of fatty tissue on the EMG signal is especially important when the EMG signal from *RA* muscle is analysed.

The results obtained also indicate that during activation of *RA* muscle at low levels of load, fatty tissue located between the muscle and the electrode may influence the recording of the EMG signal, which is also confirmed by other researchers [15], [16]. However, at higher force values (above 30% MVC) disruptions caused by fatty tissue occur to a lesser degree.

The factors analysed (fatty tissue and force level) affect the EMG signal in a combined manner which means a difficulty in determining clearly the impact of a single factor on the tested parameters of the EMG signal. In addition, the EMG signal is also affected by other factors, such as skin resistance, which were not included in the analysis.

However, it should be noted that in the present study the examined parameter FT describing the body fat layer was measured from the *biceps brachii* muscle, which represents the whole body fat layer, while the results obtained from particular muscles could be affected by the local distribution of fatty tissue in the vicinity of these muscles.

The results of the study indicate that both the fatty tissue layer and the force level influence the EMG signal parameters; however, statistically significant differences in the EMG signal parameters caused by the fatty tissue layer occur only in *RA* muscle. This suggests that the influence of fatty tissue layer on the EMG signal depends on the muscle examined, which can be associated with the proportion of type I and type II muscle fibers. In order to determine precisely how the influence of the fat layer on the EMG signal is associated with the type of muscle, further studies are necessary.

5. Conclusions

The results of the study suggest that the EMG signal is sensitive to fatty tissue layer. However, the influence of fatty tissue layer on the EMG signal is dependent on the muscle examined. The analysis of the dependence of the EMG signal on fatty tissue layer based on more detailed parameters of the power spectrum is desirable.

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