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# Optoelectronic and electromyographic study of the erector spinae muscle in female patient aged 8 with scoliosis

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## Abstract

The aim of the research was an optoelectronic and electromyographic analysis of the erector spinae muscle in patient aged 8. For the analysis there were used Diers Formetric III 4D system and Noraxon TeleMyo DTS receiver. The first one is used for optoelectronical defining of the curvature of the spine. In turn, Noraxon is used for recording and analyzing the myoelectric signals coming from the muscle. Two measurements were carried out at the interval of six months. Depending on the segment of the spine, and also whether the mean amplitude or frequency was examined, the measurements showed a higher frequency for both segments in the concave side while the larger amplitude in the concave side only in the thoracic spine. In the lumbar spine the amplitude was higher in the convex side.

**Key words**: optoelectronics, electromyography, Diers Formetric III 4D, Noraxon TeleMyo DTS, scoliosis

## Introduction

Electromyography test (EMG) is a method of receiving and analyzing the myoelectric signals, caused by selective permeation of sodium and potassium ions in the cell membranes of the muscle fibres [1,2]. In physiotherapy EMG is used to monitor the nervous and muscular activity, during the functional movements, work or training [3,4]. Measurement can be made by using surface electromyography or by intramuscular injection [5,6]. First one is a recording of muscles action potentials, registered on a skin, and followed by their involuntary or intentional stimulation [7,8]. Second method, more painful and more invasive, involves puncturing with intramuscular needles [9]. Ali and Sundaraj demostrated that through the SEMG studying, we can monitor the fatigue of different muscle groups simultaneously [10]. Żuk came in his studies to similar conclusions. He noticed that a higher mean amplitude of EMG signal occured on the convex side of vertebral column [11]. Amplitude of electrical discharge in the EMG study reflects a muscle tension. By testing the amplitude of the signal, we can indicate phases of higher or lower muscle activity. It depends on many factors which includes: diameter of muscle fibers, distances of active muscle fibers from the place of detection (amount of fat), stuff features of electrodes, distance between electrodes, physical features of electric current flow on the way muscle – electrode, disruptions from the other muscles and disruptions of external environment (electrostatic and electromagnetic fields). The goal is to get a signal without as many distortions as possible, so that's why the type of electrodes, their mounting, type of equipment and patient preparation plays a key role in obtaining a reliable recording. Frequency of EMG signal spectrum is used to evaluate the degree of muscle fatigue, together with the estimation of amplitude signal changes. Most important parameters in measurement of EMG frequency are mean value, median and also their changes in time domain of muscle contractions – fatigue tests. During submaximal contractions, analyzed parameters, depending on the amplitude and frequency, are changing due to muscle fatigue. Classical tests requires a constant level of load, together with well defined angular position/muscle length. As a result of the recruitment of motor units, amplitude shows an increase, while a mean value or frequency median of total power spectrum shows a decrease with contraction time. Causes of this decrease may be different, for example a decrease in the rate of conduction of motor functional potentials through the cell membrane. Regression coefficient of the median inclination or average frequency may be used as a non-invasive fatigue coefficient for a measured muscle. In some fatigue tests, the opposite results have been obtained: an increase in frequency and decrease in amplitude. This phenomenon is rarely described in literature, and it can be explained by migration of muscle activity between synergistic muscles and reduction of antagonist coactivation. Optoelectronic measurement by DIERS system allows for three-dimensional analysis of patient's back and spine. Results are given in a very detailed way, and through the fast image transmission to the computer, analysis is available immediately after examination. By photogrammetry method and image processing it is possible to make a three-dimensional reconstruction of the back [12.13]. Genuineness of the results obtained by DIERS has been authenticated by comparison and analysis with about 500 x-ray pictures [14]. Scoliosis is a deflection of the spine, in which the angle measured by Cobb method on the anterior-posterior radiogram, made in the habitual standing position, is at least 10° [15-18]. Deflection below 10° is defined as scoliotic posture. In 1% of a population of growing-up people, scoliosis requires treatment. In Poland this is about 5000 patients from every year. Etiology of scoliosis is not fully understood [19,20]. Attention is drawn to the uneven increase of intervertebral discs, and also to the lack of balance in core muscles [21,22]. Furthermore, currently the concept which has got the most supporters is a multifactorial, including genetical (CHD7 gene) conditioned pathology of central nervous system, which causes changes in postural system [23,24]. Among children and adolescents with scoliosis the main problem is the risk of progression of distortion [25]. Early detection reduces the risk of surgical intervention [26]. Age 5 - 8 years is considered as a key for posturogenesis, because most of the postural defects are diagnosed during this period. This is related with the beginning of intensive growth of the child, as well as with modification of the way of life, that consist on the transition from individually regulated, free activity into an imposed, often a several hours regime of being in a sitting position, which is often incorrect [27]. In separated studies, Bunnell and Negrini estimated that the risk of scoliosis progression in children's initial phase of intensive growth was 20% at 10° of spinal curvature, 60% at 20°, and 90% at 30° of curvature [28,29]. In the treatment of scoliosis a particularly important role plays a deep muscles of the back, which as a whole are called the erector spinae. Conservative methods of scoliosis treatment are exercises, braces and postural education [30,31].

The aim of the research was an optoelectronic and electromyographic analysis of the erector spinae muscle in female patient aged 8.

## Material and method

An 8-year-old girl took part in electromyographic test of erector spinae muscle. In 2016, when she went to the Świętokrzyskie Rehabilitation Centre in Czarnecka Góra, a left-convex scoliosis in thoracic and lumbar spine has been detected. Scoliosis has been diagnosed on the basis of x-rays. Rehabilitation in the Centre took 4 weeks. In November 2016 and May 2017 patient went to Laboratory of Posturology on the Faculty of Medicine and Health Sciences at the Jan Kochanowski University in Kielce. Surface electromyography and optoelectronic method of spine examination have been performed. Electromyographic analysis was performed by using Noraxon Tele Myo DTS, a 12-channel receiver (Fig. 2). Pre-gelled electrodes with diameter of 3 cm have been used. Erector spinae muscle was tested in the thoracic and lumbar parts of the spine, both on the left and on the right side. The measurement was held in four positions: habitual standing position, prone position, prone position with raised torso and prone position with raised straight legs. Each test took 10 seconds. Raw signal of electromyographic recording was presented in the form of a bar chart. It includes a mean frequency of erector spinae muscle tension expressed in hertz (Hz) and its median, and also a mean amplitude of this muscle, expressed in microvolts (μV). Optoelectronic method of spine diagnosis was performed using the Diers Formetric III 4D system (Fig. 1). It allows to make an assessment of lateral deviation of the thoracic and lumbar spine in a standing position. Patient stayed in a darkened room, back to the camera, at the distance of about three meters. The measurement lasted of about five seconds. It has been obtained a three-dimensional image of back, that includes scoliosis angle and vertebral rotation.

## Results

In optoelectronic examination of the spine, conducted in November 2016 and made by Diers Formetric III 4D the following measurement results were obtained:

- trunk length VP-DM = 336 mm,
- dimple distance DL-DR = 87 mm,
- trunk imbalance VP-DM = 2 mm R,
- pelvic skewness DL-DR mm = 0 mm,
- pelvic torsion DL-DR ° = 2° L,
- kyphotic angle ICT-ITL (max.) ° = 52°,
- lordotic angle ITL-ITS (max.) ° = 47°,
- surface rotation (+max.)° = 5 ° R ~ T 4,
- surface rotation (-max.) ° = 3 ° L ~ L 2,
- lateral deviation VPDM (+max.) = 3 mm R ~ L 1,
- lateral deviation VPDM (- max.) = 4 mm L ~ T 4.

Measurement made by DIERS showed a lateral deviation of thoracic spine at the level of Th 4 to the left side of 4 mm, which means that at this part of the spine, there is a left-convex scoliosis. In turn, the right erector spinae muscle was on concave side of thoracic spine. In lumbar segment, by optoelectronic analysis, it has been found out a lateral deviation to the right side, at the level of L 1 of 3 mm, which proves about right-convex scoliosis. Left side of this part of vertebral column was concave (Fig. 3). In electromyographic study of erector spinae muscles it has been marked a mean frequency and its median, expressed in Hertz (Hz), and amplitude expressed in µV. In habitual standing position of examined patient, in thoracic spine mean frequency was 83,6 Hz for left-convex side, and 91,3 Hz for right-concave side. Median was 68,7 Hz for left and 79,6 Hz for right side. In lumbar segment frequency was 105 Hz for concave, and 50,8 Hz for convex side. The result of median was respectively 88,8 Hz and 47 Hz. In prone position patient achieved the following results: mean frequency of thoracic spine was 81,2 Hz on the left-convex side, and on the concave side – 93,4 Hz. In turn, median was 66,1 Hz on convex and 81,5 Hz on concave side of the spine. In lumbar spine, the frequency of left erector spinae muscle was 105 Hz, and right – 50,4 Hz. Median frequency was 87,5 Hz on the concave side, and 45,2 Hz on the convex side. In prone position with torso raising, average frequency in thoracic spine was 83,1 Hz on the convex and 91,3 Hz on the concave side. Median was 68,2 Hz for left and 79,6 Hz for right side. For the lumbar spine, the frequency was 104 Hz for concave, and for right-convex side – 50,6 Hz. The result of median was 88 Hz for left and 46,9 Hz for right side. In a prone position with straight legs raising, in thoracic spine, left erector spinae muscle achieved a mean frequency of 87,1 Hz, and right – 91,1 Hz. The result of median was 71,7 Hz on the convex side and 79 Hz on concave. For the lumbar part, average frequency on the concave side was 108 Hz, and on convex 50,7 Hz. Median was respectively 90,4 Hz and 45,7 Hz (Fig. 4).

In a habitual standing position, mean amplitude of erector spinae muscle in thoracic spine was 25,2 μV on the left-convex side, and for concave – 71,9 μV. In lumbar part, average amplitude on the concave side was 34,3 μV and on the convex – 119 μV. In a prone position in thoracic segment amplitude was 25,8 μV for convex and 69,9 μV for concave side. In case of lumbar spine, result for concave side was 34,8 μV, and for right-convex side 126 μV. In prone position with torso raising, mean amplitude in thoracic spine was 22,6 μV on the left-convex side, and 65,8 μV on the concave side. In case of lumbar spine, there were following results: 30,9 μV for concave and 104 μV for convex side. In prone position with straight legs raising, average amplitude in thoracic part was 22 μV for convex side, and for concave – 66,6 μV. In turn, in lumbar segment mean amplitude was respectively 29,9 μV for concave and 106 μV for convex side of vertebral column. In optoelectronic study of the spine, conducted in May 2017 and made by Diers Formetric III 4D the following measurement results were obtained:

- trunk length VP-DM = 335 mm,
- dimple distance DL-DR = 87 mm,
- trunk imbalance VP-DM = 5 mm L,
- pelvic skewness DL-DR mm = 3 mm L,
- pelvic torsion DL-DR ° = 2° R,
- kyphotic angle ICT-ITL (max.) ° = 48°,
- lordotic angle ITL-ITS (max.) ° = 44°,
- surface rotation (+max.)° = 4 ° R ~ C7,
- surface rotation (-max.) ° = 4 ° L ~ L1,
- lateral deviation VPDM (+max.) = 5 mm R ~ L1,
- lateral deviation VPDM (- max.) = 0 mm L ~ T1.

DIERS test showed a lateral deviation of the spine on the right-convex side of 5 mm in the lumbar spine L1. No lateral deviation has been observed in thoracic spine. Moreover, in comparison with previous studies, the general deviation of torso length has increased from the vertical of 3 mm to the left side (from 2 mm to 5 mm). Also there was a pelvic skewness of 3 mm to the left side in comparison to lack of any skewness before. In electromyographic measurement in a standing position, mean frequency of erector spinae muscle tension in thoracic spine was distributed evenly, and it was 60,3 Hz to the left side, and 60,4 Hz to the right. In turn, in the lumbar spine the measurement was 75,4 Hz for left, concave side, and 64,9 Hz for right, convex side. In prone position average frequency of tension in thoracic part was o n the left side 26,9 Hz, and 71,3 Hz on the right side of vertebral column. In the lumbar spine, values of mean frequency were distributed evenly, and were 24,7 Hz for left, and 24,8 Hz for right side. To the prone position with torso raising in thoracic spine, frequency was 75,9 Hz for left erector spinae muscle and 80,1 Hz for right. In lumbar spine tension measurements gave the result of 108 Hz on the left-concave side and 96,9 Hz on the right-convex. In the prone position with straight legs raising in thoracic segment average frequency was 45,3 Hz for left and 67,1 Hz for right erector spinae muscle. In lumbar part values were 33,9 Hz for left side and 90,7 Hz for right. In case of mean amplitude of tension in patient in habitual standing position in thoracic spine the result was 21,4 µV on the left side and 19,2 µV on the right side. In lumbar spine measurement was 18,6 µV on left and 15,7 µV on right side. In prone position average amplitude in thoracic part was 8,49 µV for left erector spinae muscle and 5,03 µV for right. In case of lumbar spine, result of examination was 6,19 µV on the left side and 6,81 µV on right side. In prone position with torso raising in thoracic part, mean amplitude was 42,7 µV for left and 36,4 µV for right erector spinae muscle. In lumbar segment, measurement was 64,1 µV on the left side and 69,2 µV on the right side. For the prone position with straight legs raising, mean amplitude for the thoracic spine was 18,2 µV on the left side, and 13,4 µV on the right. For the lumbar spine, the results of average amplitude were 139 µV on the left and 80,3 µV on right side.

## Discussion

Patient went to Świętokrzyskie Rehabilitation Centre with left-convex scoliosis of the lumbar and thoracic spine, diagnosed on the basis of x-rays. After rehabilitation, there is a significant improvement in DIERS optoelectronic recording. Measurements performed in November 2016 showed a general right-convex deviation from the vertical torso length VP-DM of 2 mm to the right. Lateral deviation of torso length at the level of Th 4 in thoracic spine was 4 mm to the left, convex side. In lumbar spine the convex at the level of L 1 was 3 mm to the right side. Mean frequency was higher on the concave side, and there the muscle tension was also higher. It concerns both the thoracic and lumbar spine, in each of the four examined positions. On the convex side, mean muscle tension was lower in both tested parts of the vertebral column. Value of erector spinae muscle tension was similar at the level of thoracic spine. Greater difference in muscle tension was in the lumbar spine. During the measurements of mean amplitude of erector spinae muscle tension in thoracic spine, average amplitudes in each tested positions were higher on the concave side. This is compatible with measurements made by DIERS, which showed a slightly deviations of torso length from the vertical to the right side. Optoelectronic studies made by DIERS in May 2017 in a standing position revealed lack of lateral deviation in a thoracic part of the spine. EMG measurement in that position showed a uniform frequency of tension in both erector spinae muscles. It was 60,3 Hz on the left side and 60,4 Hz on the right. In case of detected by DIERS method right-convex lateral deviation of lumbar spine, mean frequency was lower on the convex side and was 64,9 Hz. On the concave side, the measurement was 75,4 Hz. In every each of the other starting positions in the thoracic part, frequency of erector spinae muscle tension was greater on the right side. In case of the lumbar spine, only in a prone position the frequency was symmetrical on both sides of the spine. During the torso raising the frequency was slightly higher on the left-concave side, while during the straight legs raising, a significantly higher frequency of tension was on the right-convex side. In the study of mean amplitude in each of the examined positions of the thoracic spine, the results were higher on the left side. In case of measurements in lumbar part, average amplitude was higher on the concave side in the habitual standing position and during the straight legs raising. In turn, in a prone position and in a prone position with raised torso, the amplitude of erector spinae muscle tension was higher on the right-convex side.  In the study of mean frequency in thoracic spine from May 2017 with lack of lateral deviation of the vertebral column, in each of four measurements, in four starting positions, the result was higher in case of the right erector spinae muscle. Only in the examination in habitual standing position frequency of the left muscle tension was equal to frequency on the right side. In electromyographic study of mean frequency in lumbar spine only in prone position with straight legs raising, the result was higher on the convex side. In three other positions, average frequency of tension was greater on the concave side. In the prone position, values on the concave and convex side were similar. In case when the lateral deviation of thoracic spine wasn't found in the examination, in each of studies, mean amplitude was higher on the left side, opposite to measurements of frequency. When the right-convex side of the lumbar spine was found out, in two cases the average amplitude was greater on the convex side, and in two cases on the concave. Comparing both tests, if the lateral deviation was detected by optoelectronic method, it has been stated that the higher frequency in the thoracic spine was on the concave side. For the lumbar part, in seven cases for eight, mean frequency was greater on the concave side of the vertebral column. In measurements of average amplitude of the thoracic spine, values for erector spinae muscle were higher on the concave side. In lumbar spine, in six cases for eight, amplitude was higher on the convex side. It coincides with studies made by Żuk, in which he detected a higher amplitude on the convex side of the vertebral column [11].

## Conclusions

1. On the basis of electromyographic analysis it can be stated, on which side of the spine, muscles are more contracted, and on which are relaxed.
2. Higher mean frequency occurs more often on the concave side of the spine.
3. Value of mean amplitude depends on the examined segment of the spine, but generally results are higher on the convex side.

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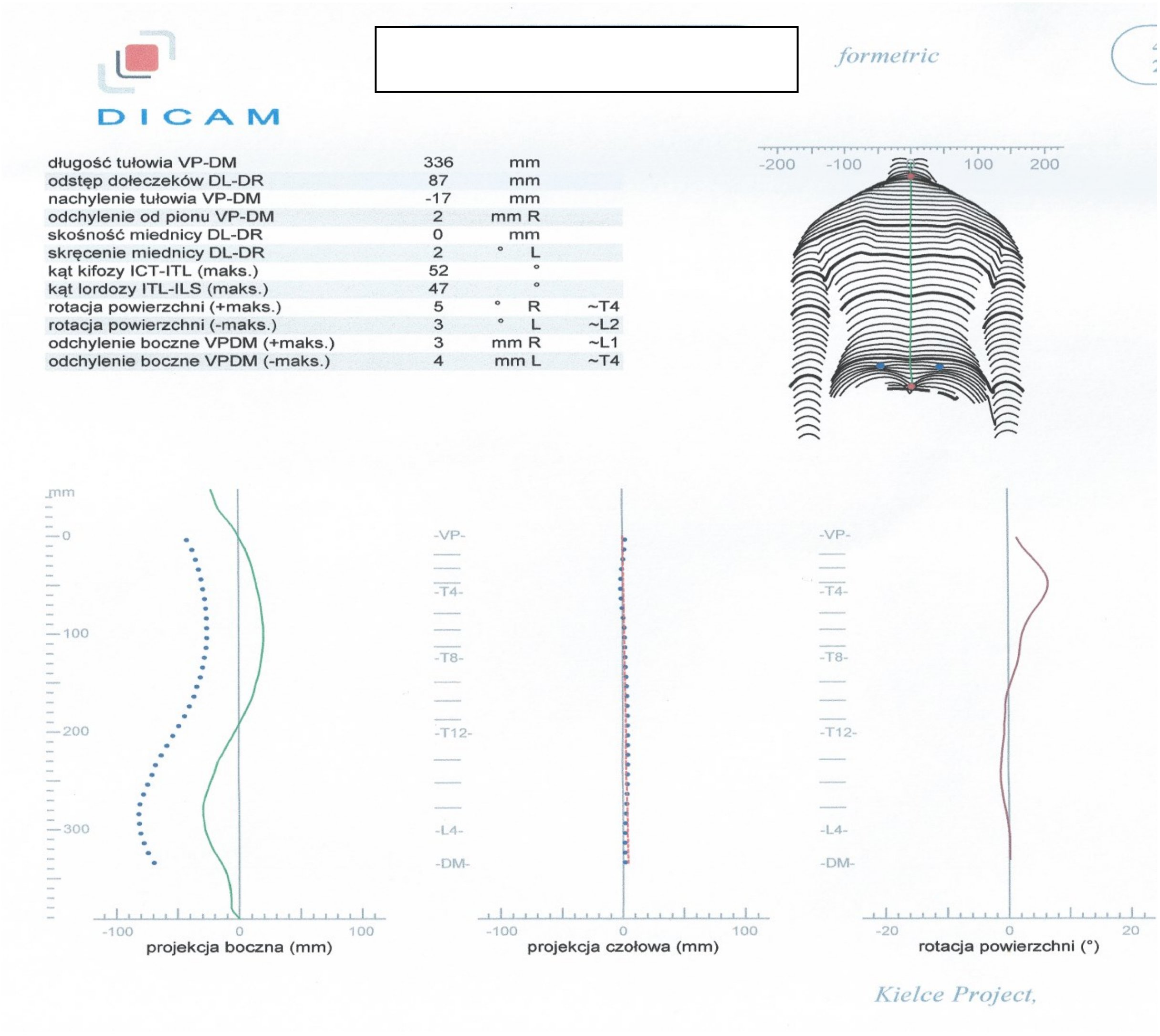
Figure 1. DIERS Formetric III 4 D system

Figure 2. Noraxon TeleMyo DTS receiver



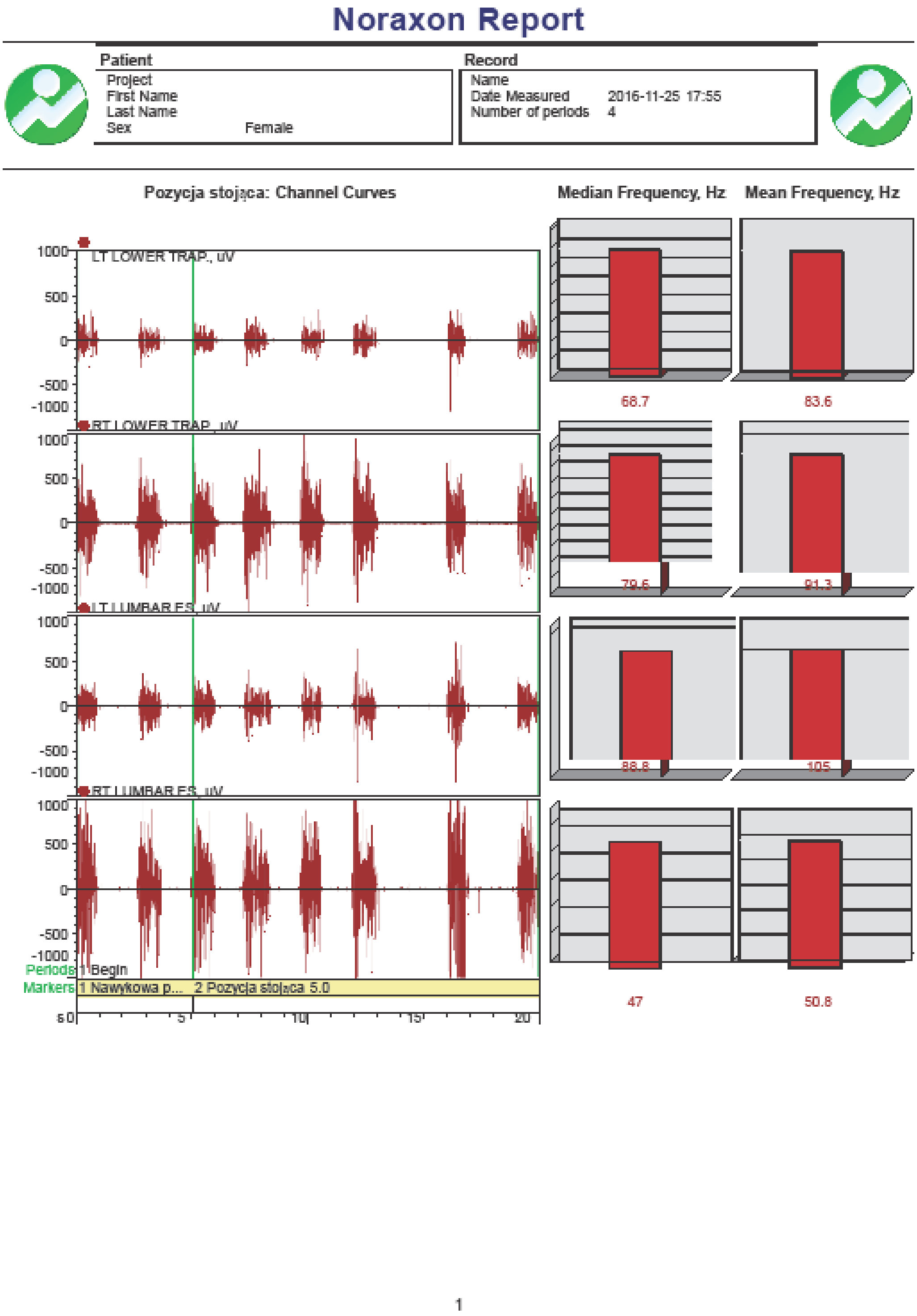
DICAM

[redacted]

formetric

| | | | |
|---|---|---|---|
| długość tułowia VP-DM | 336 | mm | |
| odstęp dołeczeków DL-DR | 87 | mm | |
| nachylenie tułowia VP-DM | -17 | mm | |
| odchylenie od pionu VP-DM | 2 | mm R | |
| skośność miednicy DL-DR | 0 | mm | |
| skręcenie miednicy DL-DR | 2 | ° L | |
| kąt kifozy ICT-ITL (maks.) | 52 | ° | |
| kąt lordozy ITL-ILS (maks.) | 47 | ° | |
| rotacja powierzchni (+maks.) | 5 | ° R | ~T4 |
| rotacja powierzchni (-maks.) | 3 | ° L | ~L2 |
| odchylenie boczne VPDM (+maks.) | 3 | mm R | ~L1 |
| odchylenie boczne VPDM (-maks.) | 4 | mm L | ~T4 |

Figure 3. Spine measurement made by Diers Formetric III 4D (November 2016)



**Noraxon Report**

**Patient**
Project
First Name
Last Name
Sex Female

**Record**
Name
Date Measured 2016-11-25 17:55
Number of periods 4

| Pozycja stojąca: Channel Curves | Median Frequency, Hz | Mean Frequency, Hz |
|---|---|---|
| LT LOWER TRAP., uV | 68.7 | 83.6 |
| RT LOWER TRAP., uV | 79.6 | 91.3 |
| LT LUMBAR ES, uV | 88.8 | 105 |
| RT LUMBAR ES, uV | 47 | 50.8 |

Periods 1 Begin
Markers 1 Nawykowa p... 2 Pozycja stojąca 5.0

Figure 4. Electromyographic measurement of mean frequency of erector spinae muscle in a standing position (November 2016)