*Acta of Bioengineering and Biomechanics*
*Vol. 11, No. 1, 2009*

# Symmetry of muscle activity during abdominal exercises

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In this study, the symmetry of EMG activity of right and left parts of rectus abdominis, erector spinae, rectus femoris has been tested during isometric exercises. Subjects ($N = 3$) were selected from the university population. In each of nine isometric exercises, the position of lower and upper extremities is different in relation to the upper body. Electromyographic signals were recorded from left and right parts of selected muscles at 1000 Hz sampling frequency. Differences in EMG activity between specific exercises for left and right parts of each muscle were tested for significance with a one-way ANOVA. It was concluded that EMG activity of left and right sides of rectus abdominis and rectus femoris does not differ significantly; nevertheless statistically important differences were noticed between left and right sides of erector spine. These findings provide more detailed knowledge and understanding of different forms of abdominal exercises.

*Key words*: *muscles activity, EMG, abdominal exercises, symmetry*

## 1. Introduction

One of the most important functions of abdominal muscles is stabilising the spinal column. A powerful muscle corset around the spine increases spinal stability and prevents overloading of the spine. The research [1] shows that 50% of adult working population suffers from the *low back pain* syndrome (LBP). One of the causes of this condition is the fact that spinal ligaments are not able to support loads even significantly smaller than the body weight. This causes asymmetric pressure on intervertebral discs resulting in pain. As the external loads in the human muscular system are transmitted in sequence by muscles, ligaments, joints and bones, weakening the muscles can cause problems even with relatively small loads experienced in everyday life. In a natural process, along with the ageing of the system, the muscle fibres decrease. The decrease of muscle fibres results in a decrease in muscle strength and a decline in their functions. One of their major functions is dumping of external loads. The measurable effect of this process is a decline in muscle strength in elderly people. In order to stop or even revert the process, the muscles need to be strengthened by power-building exercises [2].

The process described above also affects the muscles referred to in the literature as the *muscle corset*. The role of these muscles consists primarily in stabilising the spine (the stabilising functions of these muscles) during movements performed by other muscles. Therefore, in many studies it has been emphasized that strengthening these muscles is vital for preventing spinal pains. It has been observed that a general exercise routine is ineffective in reduction of the *low back pain* syndrome [3]. Consequently, many studies analyze the participation and activity of muscles in various power-building exercises [4]–[8]. In order to effectively prevent spinal pain, efforts have been made to develop exercises aimed at strengthening the muscles which stabilise the spine [9]–[10]. This is why the quantitative identification of abdominal muscles is so vital. One of the problems that need to be resolved is the symmetry of muscular activity in the exercises meant to stabilise the spine. The aim of the experi-

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Received: January 9th, 2008
Accepted for publication: December 11th, 2008

ment is to determine whether symmetrical exercises actually produce symmetrical muscular action.

## 2. Material and methods

### 2.1. Experimental procedures

The study was carried out on three volunteer female students (healthy, with no spinal conditions) participating in a fitness instructor course. To maximize the representativeness of the results obtained, the subjects were selected within one gender (female), within a similar age group of 22–23 years, as well as similar physical activity level and habitus. All subjects were right-handed.

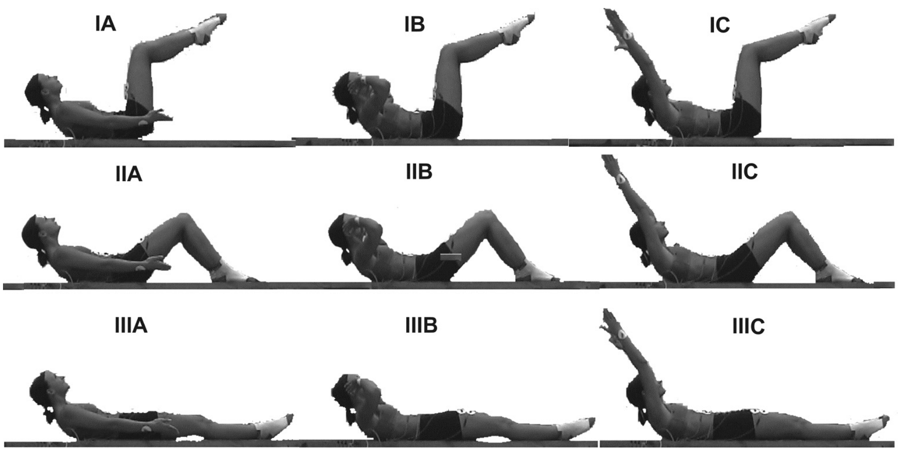
The study was performed at the Biomechanical Analysis Laboratory of the Department of Biomechanics at the University School of Physical Education in Wrocław (PN-EN ISO 9001:2001).

In the experiment, the EMG activity of the muscles was recorded with bipolar surface electrodes with solid gel Ag/AgCl (Bio Lead-Lok, Polska). The complete set consisted of six pairs of active electrodes and one reference electrode. Active electrodes were placed on the muscle bellies along the longitudinal axis of the muscles. The electrical activity was recorded for the right and left sides of the following muscles: rectus abdominis, erector spinae, and rectus femoris. The center-to-center distance between the electrodes was 6.5 cm. The reference electrode was attached to the skin in an electrically neutral location – the greater trochanter of the femoral bone. The electrodes were fitted with disposable self-adhesive rings. The positioning of electrodes was based on the principles of optimal EMG signal reception known from the literature [11] as well as on the muscular structure [12], taking into account the individual anatomical differences between the subjects. Another criterion for the choice of muscles was their ability to receive myopotentials isolated from signals from other muscles. This is why only surface muscles with large and easily identifiable shapes were selected. The EMG data were collected by the use of an eight-channel electromyograph Bortec "Octopus" (Bortec Electronics Inc., Calgary, Alberta; CA). The EMG signals were collected simultaneously from all the electrodes in order to record the activity level of the selected muscles. The EMG data were sampled at 1000 Hz.

The EMG signal in our experiment was not normalized to the maximum voluntary isometric contraction (MVIC). The signal should be normalized if signals obtained for the activity of various muscles in various movement tasks are compared. As humans are characterized by dynamic asymmetry, displayed by differences in the strength of the left and right sides of the body, one can assume that the asymmetry is also found in the EMG activity. If the EMG signals in particular tasks were compared to normalized values, the potential differences in the activities of the muscles on the right and left sides would not be observable. A similar approach to the analysis of the EMG signal of the muscles on the right and left sides of the body was adopted by other authors [13].

### 2.2. Experiment structure

Each of the subjects was asked to perform three groups of abdominal muscles' exercises at three different positions of upper and lower limbs, which together makes up nine exercise combinations (exercises A-1, B-1, C-1, A-2, B-2, C-2, A-3, B-3, C-3) (the figure). The exercises were done in static positions. The duration of one isometric exercise was five sec-




Characteristics of exercises in respect of the position of lower and upper limbs onds. The exercises were intersected with one-minute rest intervals which helped relax the muscles. Each exercise was repeated three times. The sequence of execution of individual tests was randomly determined, which meant a different combination of exercises for each subject. The test experiment was repeated on the next day.

The analysed exercises consisted in isometric action of abdominal muscles in a precisely specified position, i.e. lying on the back with the shoulders raised above the floor and the lumbar part of the spine contacting the floor. Individual exercises differed in the position of the lower and upper limbs in relation to the trunk (the figure). Three positions of the lower limbs and three positions of the upper limbs were selected, thus making nine exercise combinations. Based on the position of the lower limbs in relation to the trunk, the exercises were divided into three groups (1, 2, 3).

*Group 1.* The exercises in this group were executed in a static supine position with the shoulder girdle raised above the floor, the lumbar part of the spine contacting the floor and the lower limbs raised above the floor with the hip and knee joint flexed at the angle of 90 degrees.

*Group 2*. In supine position, head and upper body as above, feet resting on the floor, lower limbs flexed at hip (90 degrees) and knee (90 degrees).

*Group 3.* In supine position, head and upper body as in group 1, the angle in the hip and knee joint at 180 degrees, lower limbs lying down on the floor.

For the three combinations of lower limb positions (1, 2, 3) there were three selected positions of the upper limbs (A, B, C).

*Upper limbs position A*. In exercises (A-1, A-2, A-3), the upper limbs positioned alongside the upper body, parallel to the floor, extended in the elbow joints. Hands with the palmar side upwards.

*Upper limbs position B*. In exercises (B-1, B-2, B-3), hands with the palmar side touching the neck. Upper limbs abducted and flexed in the elbow and humeral joints.

*Upper limbs position C.* In exercises (C-1, C-2, C-3), upper limbs raised up, shoulders at the head height, elbow joints extended. The palmar side of the hands directed inwards.

The isometric exercises selected for analysis involve, to a different degree, the abdominal muscles and flexors of the hip joint. Additionally, the selected exercises are initial positions for dynamic exercises of the abdominal muscles practiced at varying forms of fitness activities.

Subjects did 6 trials for each assigned task, 3 on one day and 3 on the next. This means that the statistical analysis involved 18 data items for each task (6 trials × 3 subjects).

The raw EMG signal was recorded using a PC computer and stored with the Bioware program. The ‘Analizator’ program was used to determine the absolute value of the electrical signals and the moving mean (with 3 s step). The moving mean values can be interpreted as the result of low pass filtering. Subtracting the moving mean values from the raw signal eliminated the low frequency component, which is the redundant noise in the frequency analysis.

The output data from the ‘Analizator’ program were transferred to the MS Excel spreadsheet, which was used to prepare the data for the statistical analysis carried out using the Statistica 5.0 software. For statistical analysis a one-factor, repeated-measures analysis of variance (ANOVA) was used, and post hoc analyses were performed with the NIR test. Additionally, the statistical analysis included the coefficient of variation (the ratio of the standard deviation to the mean value) usually given in per cent. It is assumed that if this coefficient is lower than 10%, the characteristics show no statistically significant variation. On the other hand, high values of the coefficient indicate variation, which is heterogeneity, of the characteristics tested. The coefficient can be applied when one needs to assess the variation of:

a) a number of populations for the same characteristics,

b) one population for different characteristics.

# 3. Results

The analysis of the EMG activity of selected abdominal and lumbar muscles was performed in exercises with the induced muscular contraction appropriate for retaining the same static trunk position for different muscle torques and external loads. The change of the muscle torque and external load was made by changing the position of lower and upper limbs (see the description of the exercises in the ‘Experiment structure’ section). A change in the conditions of the abdominal exercises resulted in changing the electrical activity of rectus abdominis. Although the right-side part of the muscle showed higher values of the action potential, the statistical analysis (ANOVA) indicated in each exercise group analyzed no statistically significant differences in the electrical activity between the right and left sides of the examined muscle (table 1).

Table 1. Mean values and standard deviation of abdominal muscle myopotential amplitude [μV] for three exercise groups (I, II, III) and three positions of upper limbs (A, B, C)

| Type of exercise | Side | Exercise group I $\bar{x} \pm SD$ | Exercise group II $\bar{x} \pm SD$ | Exercise group III $\bar{x} \pm SD$ |
|---|---|---|---|---|
| A | *R* | 70.13 ± 36.41 | 87.96 ± 47.59 | 89.72 ± 36.23 |
| | *L* | 76.50 ± 17.99 | 66.31 ± 21.55 | 78.71 ± 17.70 |
| B | *R* | 111.17 ± 51.91 | 104.05 ± 46.37 | 100.13 ± 35.78 |
| | *L* | 88.62 ± 28.04 | 83.70 ± 27.57 | 86.08 ± 27.48 |
| C | *R* | 113.06 ± 16.28 | 111.86 ± 30.96 | 106.93 ± 26.02 |
| | *L* | 93.47 ± 42.97 | 88.18± 28.93 | 94.41 ± 29.71 |

*R* – activity of the right side of rectus abdominis, *L* – activity of the left side of rectus abdominis.

Table 2. Mean values and standard deviation of lumbar muscle myopotential amplitude [μV] for three exercise groups (I, II, III) and three positions of upper limbs (A, B, C)

| Type of exercise | Side | Exercise group I $\bar{x} \pm SD$ | Exercise group II $\bar{x} \pm SD$ | Exercise group III $\bar{x} \pm SD$ |
|---|---|---|---|---|
| A | *R* | 34.55 ± 24.71* | 28.81 ± 13.82* | 33.14 ± 12.29* |
| | *L* | 14.64 ± 5.40 | 14.37 ± 3.88 | 17.65 ± 6.09 |
| B | *R* | 39.36 ± 17.92* | 31.42 ± 19.19* | 35.63 ± 14.93* |
| | *L* | 17.77 ± 3.69 | 15.18 ± 2.50 | 16.54 ± 3.66 |
| C | *R* | 15.67 ± 2.03* | 14.91 ± 4.32* | 17.00 ± 4.54* |
| | *L* | 10.86 ± 1.51 | 10.07 ± 1.01 | 11.96 ± 2.45 |

* $\alpha < 0.05$.
*R* – activity of the right side of erector spinae, *L* – activity of the left side of erector spinae.

Table 3. Mean values and standard deviation of femoris muscle myopotential amplitude [μV] for three exercise groups (I, II, III) and three positions of upper limbs (A, B, C)

| Type of exercise | Side | Exercise group I $\bar{x} \pm SD$ | Exercise group II $\bar{x} \pm SD$ | Exercise group III $\bar{x} \pm SD$ |
|---|---|---|---|---|
| A | *R* | 62.03±10.59 | 10.97±1.36 | 23.12±9.70 |
| | *L* | 53.30±18.61 | 12.53±2.60 | 23.15±6.97 |
| B | *R* | 43.31±20.52 | 10.50±2.16 | 16.55±6.13 |
| | *L* | 58.01±21.98 | 10.54±1.84 | 22.80±12.65 |
| C | *R* | 57.85±8.53 | 7.45±0.45 | 16.62±8.88 |
| | *L* | 52.69±14.58 | 7.52±0.30 | 19.65±11.35 |

*R* – activity of the right side of rectus femoris, *L* – activity of the left side of rectus femoris.

Table 4. Values of variation coefficient (*V*) of electrical activity of the following muscles: RA – rectus abdominis, ES – erector spinae, RF – rectus femoris [%] for three exercise groups (I, II, III) and three upper limb positions (A, B, C)

| Type of exercise | Side | Group I | | | Group II | | | Group III | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RA | ES | RF | RA | ES | RF | RA | ES | RF |
| A | *R* | 51.92 | 71.52 | 17.07 | 54.1 | 47.97 | 12.4 | 40.38 | 37.08 | 41.95 |
| | *L* | 23.52 | 36.88 | 34.91 | 32.5 | 27.00 | 20.75 | 22.49 | 34.50 | 30.11 |
| B | *R* | 46.7 | 45.53 | 47.38 | 44.56 | 61.07 | 20.57 | 35.73 | 41.90 | 37.04 |
| | *L* | 31.64 | 20.76 | 37.89 | 32.94 | 16.47 | 17.46 | 31.92 | 22.13 | 55.48 |
| C | *R* | 14.4 | 12.95 | 14.74 | 27.68 | 28.97 | **6.04** | 24.33 | 26.71 | 53.43 |
| | *L* | 45.97 | 13.90 | 27.67 | 32.81 | 10.03 | **3.98** | 31.47 | 20.48 | 57.76 |

*R* – variation coefficient of right side of muscle examined.
*L* – variation coefficient of activity of left side of muscle examined.

As in the upper body flexing movements the erector spinae is the antagonist to rectus abdominis, it should show a similar pattern of electrical activity. However, the general ANOVA indicated statistically significant differences between the bioelectric activity of the right and left sides of the erector spinae. This is testified by the test value of $F = 35.20$ for $df = 106$ and $p = 0.00001$ (table 2).

The NIR test revealed statistically significant differences between the right and left sides of the analyzed muscle in each of the exercises in group III, in group I at the upper limb positions B and C, in group II at the upper limb positions A and C.

The statistical analysis (ANOVA) indicated in each exercise group analyzed no statistically significant differences in the electrical activity between the right and left sides of rectus femoris (table 3).

Based on the variation coefficient values presented in table 4, one can notice that the electrical activity of the muscles examined shows very high statistically significant variation. Only for the rectus femoris, the two coefficients are below 10% (table 4).

# 4. Discussion

As numerous scientific studies claim, human body is by nature asymmetric [14]. One can perceive the morphological asymmetry connected with the differences between the left side and right side body structure as well as the functional asymmetry connected with the laterality resulting from the dominant role of one of the cerebral hemispheres. A specific form of the functional asymmetry is dynamic asymmetry manifesting itself among others as differing muscular strength of the right and left upper or lower limbs. However, the results of the strength asymmetry tests are not unequivocal. The research done by DWORAK [15]–[16] and DĘBICKA [17] shows no asymmetry of isometric strength in children aged 7–14. While other authors observed the dominance of the right lower limb over the left one in youth aged 15–19. The same authors report statistically insignificant difference in the asymmetry of isometric strength of lower limbs in adults aged 20–25.

MASZTALERZ and URBANIK [18] examined the symmetry of dynamic strength and power of the lower limbs. Their results are not unequivocal either. Depending on the load value, the movement range and the movement speed in the joint, the torque and power of the right or left limb change. A change in the test conditions affected the dominance, or lack of it, of the right or left lower limb.

The spine stabilisation is performed both by lumbar and abdominal muscles. The main stabilizing activity is connected with the so-called prime and secondary stabilisers. In our study, we analyze the activity of muscles which under normal conditions perform mobility functions and only take on the stabilising function when there is a need for it. Therefore, it was assumed that in isometric exercises of abdominal muscles, the activity of the m. rectus abdominis and the m. erector spinae should show symmetry in the right and left parts of these muscles. The m. rectus abdominis showed symmetry in its activity while the m. erector spinae was involved in activity in the right side higher than in the left one. The asymmetry of lumbar muscles was also reported in a study examining the EMG activity of erector spinae and trapezius. In all the exercises analysed, the dominance in the electrical activity of the right side of the muscles was observed. On the other hand, AXLER and MCGILL [19] reported a different pattern of asymmetry. Rectus abdominis showed higher activity in its left side than in the right one. External oblique and internal oblique were more active in the right side. The authors mentioned above examined the muscular symmetry in dynamic abdominal sit-up exercises.

Our study indicates symmetry in the activity of the rectus abdominis and asymmetry (dominance of the right side) of erector spinae irrespective of external load. This may result from the fact that the experiment test subjects were not previously active sportsmen.

## Acknowledgements

This work is supported by the research grant N N404 155834 from the Polish Ministry of Science and Higher Education.

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