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# Reliability of measurements of the extension-flexion ratio with surface EMG

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**Abstract.**
**BACKGROUND:** The surface electromyography (sEMG), by evaluating the paraspinal muscle activity, may be used for diagnosis and evaluation of rehabilitation effectiveness patients with low back pain.
**OBJECTIVE:** The purpose of the study was to determine the intra- and inter-session reliability of the measurement of the activity of the lumbar erector spinae (LES) activity (extension-flexion ratio).
**METHODS:** The study included 21 asymptomatic subjects, aged 14 to 27 years, mean 23.7 $\pm$ 2.9. The LES muscle activity was assessed with using of the sEMG during forward trunk flexion and extension by two examiners. Based on the quotient of the LES muscle activity obtained during four concentric and eccentric tasks the extension-flexion ratio was calculated.
**RESULTS:** The measurements displayed excellent or fair-to-good reliability (intraclass correlation coefficient ranged from 0.90 to 0.68). The typical error and coefficient of variations, ranged from 0.34 to 0.58, and from 13.7 to 21.9, respectively.
**CONCLUSIONS:** The measurement of the extension-flexion ratio performed with the use of sEMG shows high level of intra- and inter-session reliability, suggesting that this parameter is a reliable tool in evaluation of the lumbar paraspinal muscles activity. However, the level of typical error should be taken into account.

Keywords: Reliability, typical error, surface electromyography, extension-flexion ratio

## 1. Introduction

At least once in a lifetime low back pain (LBP) affects 60% to 85% of the population and approximately 40% of adults complain of suffering from LBP at least once a year [1,2]. It is estimated that LBP affects 14% to 48% of children and adolescents [3–5]. As a result, the costs of musculoskeletal system diagnostics in subjects with LBP syndrome, as well as the costs of treatment, missed work days, and related disability, constitute a significant part of expenses incurred by healthcare systems of the majority of countries [2].

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The diagnostics of LBP patients is difficult because many of them do not present any objective pathologies of the musculoskeletal system [6]. On the other hand, some objective indicators of musculoskeletal system pathologies, revealed in imaging examinations (X-ray, MRI), are not specific for patients suffering from LBP because they also occur in asymptomatic subjects [6,7].

Therefore, some alternative methods of musculoskeletal system assessment in patients with LBP are sought [2,6,7]. One of them is surface electromyography (sEMG) [6,8–12]. It is postulated that evaluation of the paraspinal muscle activity with sEMG allows for diagnosis and evaluation of LBP subjects treatment effectiveness [8,10,13]. According to Geisser et al. the popularity of sEMG is driven by the fact that it provides an objective and non-invasive assessment of patients with LBP who do not display pathologies measurable with other methods: X-ray, MRI, or neurological tests [6].

The most commonly studied sEMG parameter for the paraspinal muscles is the flexion-relaxation phenomenon [6,9,10,14]. This phenomenon is defined as the reduction or silencing of electrical activity of the erector spinae during complete flexion of the trunk [6, 9,10,14]. The flexion-relaxation phenomenon is not observed in patients with LBP [9,10,14].

The lack of silencing of electrical activity of spinal muscles may be related to reduced spinal stabilisation during trunk flexion, and may lead to increased risk of structural damage [8,9,14,15]. Floyd and Silver (1955) have already shown that one third of patients with back pain did not achieve relaxation of lumbar erector spinae muscle activity in full trunk flexion [16].

Sihvonen et al. for assessment of the paraspinal muscles activity proposed another parameter – the extension-flexion ratio [17]. This parameter is determined on the basis of the ratio of the lumbar paraspinal muscles activity reached during the trunk flexion and return to a straight standing position [17]. In healthy subjects, the proper pattern of the lumbar erector spinae muscle activity consists in increased muscle activity in the initial phase of the trunk flexion and should gradually decrease during forward bending until it silences at the end of the range of motion. During the extension, the muscle activity should gradually increase [17]. Although the authors reported good reliability of measurements of the paraspinal muscles activity, performed during the trunk flexion and extension, unfortunately they did not analyse the reliability of the proposed ratio [17]. Other authors, using this coefficient in their research, did not verify its reliability either [18].

What is important, the extension-flexion ratio allows for detecting incorrect back muscle activity not only in LBP patients but in subjects who currently do not suffer from back pain as well. Therefore, by this ratio, asymptomatic subjects might be evaluated and diagnosed even in pain-free condition and it may be important in prevention of LBP [17].

According to Evidence Based Medicine (EBM) requirements, each tool and research method used in the diagnostic and therapeutic process should be evaluated for reliability [19,20]. It is particularly important in surface EMG studies, because of possible extrinsic (e.g. conditions in which the measurement is taken) and intrinsic (e.g. the researcher's experience) factors being the source of measurement errors which may reduce the reliability of measurements [21]. Taken into account the rules EBM guidelines, the lack of studies assessing the reliability of extension-flexion ratio, with its simultaneous application in scientific research and clinical practice, it is important to conduct the research verifying the ratio reliability.

The purpose of this study was to determine the intra- and inter-session reliability of extension-flexion ratio measured with surface EMG.



## 2. Material and methods

### *2.1. Subjects*

The study included 21 subjects (13 male, 8 female), 14 to 27 years old (mean 23.7, SD 2.9). The inclusion criteria were as follows: (1) no LBP within the past 12 months, (2) no surgical or physiotherapeutic interventions in the trunk or lower extremities within the past 12 months, (3) no injuries of the trunk or lower extremities within the past 12 months, (4) no pregnancy within the past 12 months, (5) no physical activity within 48 hours before the beginning of the examination, and (6) no menstruation on the day of the examination.

Before the study, each subject has been informed about the study protocol and gave written informed consent for study participation. The Local Ethical Commission granted permission for this research.

### *2.2. Instrumentation*

All subjects were assessed for the lumbar erector spinae activity with the use of MyoTrace 400 device (Noraxon, USA) cooperating with MyoResearch XP Master Edition software. The EMG signals were filtered (bandwidth: 10–500 Hz) and full-wave rectified. The sampling rate was 1000 Hz. Before placement of electrodes, the skin was cleaned and, if needed, shaved. Pairs of electrodes (ARBO, Kendall, Tyco Healthcare, Germany), a 1 cm diameter coated with silver/silver chloride (Ag/AgCl), were placed 2 cm laterally from the palpated spinous processes of the vertebrae located at the level of the iliac crest. The distance between the centres of electrodes was 2 cm. Reference electrode was placed at the sacrum. The subjects were prepared and electrodes were placed in accordance with the guidelines of the SENIAM Project and with Kasman et al. protocol [21,22].

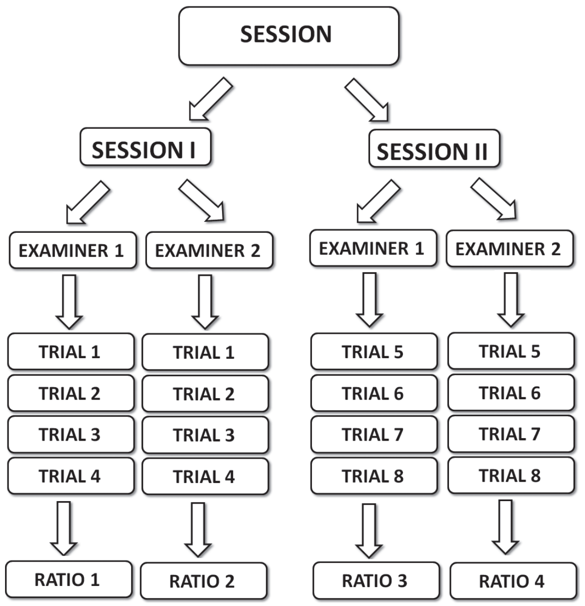


Fig. 1. Diagram flowchart of the extension-flexion ratio measurements.

### 2.3. *Protocol of the study*

Prior to the examination, each subject was fully informed about the study protocol. Additionally, examiners demonstrated the initial position and how each phase of trunk movement should be correctly performed. Before the measurement each subject performed 2–3 times all of its elements in order to be fully familiar with the character of the movements. The measurements were performed with subjects in standing position, with their lower extremities straight in knee joints, and the feet hip-width apart. The order and duration of the movements was as follows [17,18]:

(1) Posture test – a subject stands in upright, habitual position for 5 seconds,
(2) Forward trunk flexion (eccentric phase) – subject performs habitual full trunk forward bend within 5 seconds,
(3) Relaxation – subject remains 3 seconds in full trunk flexion,
(4) Trunk extension (concentric phase) – subject returns to upright, habitual position within 5 seconds.

The measurements were performed by two examiners within two sessions. During each session the application of electrodes was changed. The order of measurements, performed by both examiners, was chosen randomly. During the first session (Session I), each examiner measured in each subject EMG activity of the lumbar erector spinae muscle during four trunk flexions and extensions trials (Trials 1–4) [17]. For each trial consisting of concentric (extension) and eccentric (flexion) work, the ratio of the peak value of the sEMG signal, was evaluated [17,18].

The extension-flexion ratio was then calculated on the basis of the mean EMG activity obtained during the four trials [17]. The pattern of extension-flexion ratio measurements was shown in Fig. 1.

During the second session (Session II) each observer repeated the same protocol of measurements, like in Session I. All EMG recordings were real-time controlled by the observer on computer monitor. All measurements were performed in the presence of only the subject and one examiner. Both examiners had a similar, two-year experience in muscle activity assessment using surface EMG.

In order to assess the reliability of the measurements of the extension-flexion ratio the following procedure was adopted: (1) analysis of the intra-session intra-examiner reliability, separately for examiner 1 and 2; (2) analysis of the inter-session intra-examiner reliability, separately for examiner 1 and 2; (3) analysis of the intra-session inter-examiner reliability; (4) analysis of the inter-session inter-examiner reliability.

The results were analyzed with Statistica 7.1 (StatSoft, Poland) and Microsoft Office Excel 2003. The ANOVA and Students t-test were used. The intra- and inter-session reliability was evaluated using intraclass correlation coefficient (ICC) [23,24]. In addition, according to Hopkins, a typical error (TE) and the coefficient of variation (CV %) (in percent) were determined [24]. The value $p < 0.05$ was adopted as the level of significance while CI for estimates was 0.95%. The activity of the right lumbar erector spinae was adopted to the analysis [17].

## 3. Results

The results obtained by both examiners during Trials 1–4 and Trials 5–8 are reported in Tables 1 and 2.

There was a significant difference ($p = 0.004$) between Ratio 1 obtained by examiner 1 and Ratio 2 obtained by examiner 2 (2.86 $\pm$ 1.01 vs. 2.53 $\pm$ 0.89, respectively). There was no significant differences ($p >$ 0.05) between the remaining Ratios (Table 3).

The levels of intraclass correlations coefficient, typical errors and coefficient of variations are shown in Table 4.

Table 1
The value of ratio of the lumbar erector spinae muscle activity obtained during Trials 1–4 ($n = 21$)

| Examiner | Trial 1 M (SD) | Trial 2 M (SD) | Trial 3 M (SD) | Trial 4 M (SD) | p |
|---|---|---|---|---|---|
| Examiner 1 | 2.9 (1.12) | 2.95 (1.09) | 2.83 (1.04) | 2.77 (1.0) | 0.46 |
| Examiner 2 | 2.55 (1.05) | 2.47 (0.92) | 2.62 (0.94) | 2.5 (0.94) | 0.72 |

M – mean, SD – standard deviation.

Table 2
The value of ratio of the lumbar erector spinae muscle activity obtained during Trials 5–8 ($n = 21$)

| Examiner | Trial 5 M (SD) | Trial 6 M (SD) | Trial 7 M (SD) | Trial 8 M (SD) | P |
|---|---|---|---|---|---|
| Examiner 1 | 2.78 (0.88) | 2.81 (0.73) | 2.72 (0.81) | 2.63 (0.65) | 0.48 |
| Examiner 2 | 2.46 (0.92) | 2.75 (1.02) | 2.8 (0.85) | 2.56 (0.91) | **0.03** |

M – mean, SD – standard deviation. Significant difference ($p < 0.05$) is marked in bold.

Table 3
Mean, standard deviation and level of significant difference between particular ratios

| Ratio 1 M (SD) | Ratio 2 M (SD) | Ratio 3 M (SD) | Ratio 4 M (SD) | p |
|---|---|---|---|---|
| 2.86 (1.01) | – | 2.73 (0.69) | – | 0.43 |
| – | 2.53 (0.89) | – | 2.64 (0.86) | 0.39 |
| 2.86 (1.01) | 2.53 (0.89) | – | – | **0.004** |
| – | – | 2.73 (0.69) | 2.64 (0.86) | 0.48 |
| 2.86 (1.01) | – | – | 2.64 (0.86) | 0.12 |
| – | 2.53 (0.89) | 2.73 (0.69) | – | 0.19 |

M – mean, SD – standard deviation. Significant difference ($p < 0.05$) is marked in bold.

Table 4
The intraclass correlation coefficient, typical error and coefficient of variation for measurements of Trials 1–4 and 5–8 as well as for extension-flexion ratios

| | ICC | TE | CV (%) |
|---|---|---|---|
| Intra-session I intra-examiner agreement for examiner 1 (Trials 1–4) | 0.9 | 0.34 | 14.0 |
| Intra-session I intra-examiner agreement for examiner 2 (Trials 1–4) | 0.82 | 0.44 | 19.4 |
| Intra-session II intra-examiner agreement for examiner 1 (Trials 5–8) | 0.86 | 0.39 | 13.7 |
| Intra-session II intra-examiner agreement for examiner 2 (Trials 5–8) | 0.8 | 0.47 | 18.0 |
| Inter-session intra-examiner agreement for examiner 1 (Ratio 1–Ratio 3) | 0.77 | 0.5 | 18.3 |
| Inter-session intra-examiner agreement for examiner 2 (Ratio 2–Ratio 4) | 0.74 | 0.53 | 20.1 |
| Intra-session I inter-examiner agreement (Ratio 1–Ratio 2) | 0.88 | 0.37 | 14.6 |
| Intra-session II inter-examiner agreement (Ratio 3–Ratio 4) | 0.74 | 0.53 | 20.1 |
| Inter-session inter-examiner agreement (Ratio 1–Ratio 4) | 0.81 | 0.45 | 17.1 |
| Inter-session inter-examiner agreement (Ratio 2–Ratio 3) | 0.68 | 0.58 | 21.9 |

ICC – intraclass correlation coefficient, TE – typical error, CV – coefficient of variation.

## 4. Discussion

The purpose of this study was to determine the intra- and inter-session reliability of the assessment of the lumbar erector spinae activity based on the extension-flexion ratio measured with surface EMG. Taking into account that there has been no such study carried out yet as well as that each tool and research methods applied in the musculoskeletal system diagnostics should be verified for their reliability [19,20], the present study complements the literature by the missing analysis. It seems to be particularly important in clinical practice because the diagnostic and control examinations may be performed by different examiners.

According to Shrout and Fliess measurements may be considered excellently reliable when the intraclass correlation coefficient is $> 0.75$. For the ICC value 0.75–0.4, reliability is fair-to-good and $< 0.4$ reliability is poor [25]. Our study demonstrated that the both intra- and inter-examiner reliability of the measurements of the extension-flexion ratio was excellent or fair-to-good (intraclass correlation coefficient ranged from 0.90 to 0.68). It indicate that the measurements of the extension-flexion ratio, conducted by the two examiners both in the same session as well as in two different sessions, are reliable. However, it is worth noticed that the level of the typical error and the coefficient of variations amounts ranged from 0.34 to 0.58 and from 13.7 to 21.9, respectively. In our opinion, the possibility of this error existence should be taken into account when the measurement of extension-flexion ratio is used for diagnostic purposes and for the verification of therapeutic outcomes. It is also worth noting, that a significant difference between Trials 5–8 measured by examiner 2 ($p = 0.03$) as well as between Ratio 1 measured by examiner 1 and Ratio 2 measured by examiner 2 ($p = 0.004$) was observed. However, it seems that the level of intraclass correlation for these measurements (0.8 for Trials 5–8 performed by examiner 2, and 0.88 for Ratio 1 and 2 obtained by examiner 1 and 2) may be a basis for stating that these measurements were also reliable. However, in the further studies it is worth to verify the causes of significant difference occurrence between the results obtained during the same session by examiner 2. Especially that this difference was not noted for examiner 1 who presented the same, two-year experience in muscle assessment using surface EMG.

Sihvonen et al. first suggested that the analysis of lumbar spine muscles activity during trunk extension and flexion can be used for assessment of the musculoskeletal system both in asymptomatic subjects as well as in subjects with LBP [17]. Based on the ratio of the peak value of the sEMG signal during concentric and eccentric work, the authors reported the value of extension-flexion ratio for pain-free subjects at the level $3.2 \pm 0.8$. In our study the values of the ratio were similar, but slightly lower. For subjects with LBP, Sihvonen et al. reported the ratio at the level of 1.9 (SD 0.5). Although, the authors presented the normal values of the extension-flexion ratio, they not determined its reliability. The authors did not verify the reliability of the ratio in asymptomatic subjects as well.

Sihvonen et al. have suggested that the lower values of the ratio in patients with LBP are due to a higher level of muscle activity during trunk flexion and lower level of activity during trunk extension [17]. As they reported the extension-flexion ratio allows for detecting irregularities in muscle activity also in persons who currently do not suffer from back pain. The extension-flexion ratio may be more sensitive indicator of aberrant muscles activity than the flexion-relaxation phenomenon which may only occur in patients with present low back pain. By this ratio, healthy and unhealthy subjects might be evaluated and diagnosed even in pain-free condition [17]. Our study, as the first one, presented the reliability level of extension-flexion ratio for asymptomatic subjects. The obtained results indicate that the ratio may be a useful tool for the evaluation of the paraspinal muscles in such individuals.

The assessment of muscle activity with surface EMG is limited by factors which may influence on signal quality (e.g. preparing the locations of electrodes, the placement of electrodes, proper clothes, room temperature) [11,26]. The present study was conducted accurately according to the recommendations described in the literature so we believe that the influence of such factors was minimized [21,22]. However, the presence of these factors should be taken into account, during the interpretation of the data obtained with using EMG.

We emphasized the certain limitation of the presented study. Firstly, we have determined the reliability of extension-flexion ratio in asymptomatic subjects. Therefore, the results of the study may be used in the interpretation of the lumbar erector spinae activity only in such subjects. The further studies are also needed to evaluate the reliability of extension-flexion ratio in LBP patients. Secondly, the observed level of the Standard Deviations was high and ranged from 0.65 to 1.12. It means, that the level of extension-flexion ratio may be different in particular subjects. Therefore, the next study with larger sample size may be helpful in further evaluation of the reliability of the extension-flexio ratio.

## 5. Conclusions

1. The measurement of the extension-flexion ratio is a valid tool for evaluation of the activity of the lumbar erector spinae.
2. The high level of typical error should be taken into account during measurements interpretation. The future studies are required to verify the sources of the typical error.

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### Conflict of interest

The authors declare that they have no conflicts of interest.

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