# Przydatność analizy sEMG do oceny sekwencji pobudzeń mięśni okolicy lędźwiowo-kulszowej u pacjentów z dolegliwościami bólowymi

*Usability of sEMG analysis for the evaluation of the muscles stimulation sequence in the lumbosciatic area in patients suffering from pain in lumbar spine*

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**Streszczenie:**

**Cele pracy:** 1. Ocena związku pomiędzy zmianą sekwencji pobudzeń mięśni okolicy lędźwiowo-kulszowej a występowaniem funkcjonalnego bólu w odcinku L kręgosłupa w porównaniu do modelu Jandy.
2. Analiza różnic w zapisie elektromiografii powierzchniowej (sEMG) prawidłowego i zaburzonego wzorca rekrutacji mięśni podczas testu wyprostu w stawie biodrowym w dwóch podgrupach pacjentów, bólowych (podgrupa A) i bezbólowych (podgrupa B).
3. Ocena przydatności pomiaru sEMG w diagnozowaniu Pacjentów z bólami kręgosłupa w odcinku lędźwiowym.
**Materiał i metoda.** Do badania zakwalifikowano 61 osób w wieku 20-35 lat ze średnią wieku 25 lat (+/- 6). Grupę badaną podzielono na dwie podgrupy. Do podgrupy A zakwalifikowano 33 osoby a do podgrupy B, kontrolnej, 28 osób. Wśród badanych przeprowadzono ankietę badawczą sporządzona na potrzeby pracy. Do badaniem sekwencji pobudzeń wykorzystano pomiary uzyskane z zapisu sEMG podczas testu wyprostu w stawie biodrowym, PHE Test, (ang. Prone Hip Extension Test).
**Wyniki.** Uzyskane wyniki podczas badania wzorca rekrutacji mięśni podczas testu PHE wykazały zmienioną kolejność aktywacji u Pacjentów z podgrupy A vs podgrupy B. Wyniki testu $\chi^2$ potwierdziły istotną statystycznie zależność, osoby z objawami bólowymi kręgosłupa lędźwiowego statystycznie rzadziej wykazywały prawidłową kolejność angażowania mięśni: $\chi^2$=5,05, p=0,041. R=- 0,59 (zależność silna, ujemna).
**Wnioski.** Zmiany w schemacie rekrutacji mięśni podczas wyprostu stawu biodrowego prowadzą do przeciążeń okolicy lędźwiowo-kulszowej, przyczyniając się do powstawania bólu w odcinku lędźwiowym. Elektromiografia powierzchniowa, ze względu na możliwość uzyskania wyniku ilościowego jest przydatną metodą oceny pracy mięśni.

**Słowa kluczowe:**
test Jandy, Test wyprostu stawu biodrowego, sEMG, ból dolnego odcinka pleców

***Abstract***

**Aim of the study:** *1. Evaluation of the relationship between the change in the stimulation sequence of muscles in the lumbosciatic area and the occurrence of functional pain in the L section of the vertebral column, as compared to the Janda's model.*
*2. Analysis of the differences in the superficial electromyography (sEMG) record of a correct and disturbed pattern of muscle recruitment during the prone hip extension test in two sub-groups of patients: suffering from pain (sub-group A) and without pain (sub-group B).*
*3. Evaluation of the suitability of the sEMG measurement for making diagnoses in patients with pains in the lumbar section of the vertebral column.*
**The material and method:** *For the research, 61 persons were qualified, aged 20-35 years, with the average age 25 years (+/- 6). The tested group was divided into two sub-groups. 33 persons were qualified to sub-group A, and to sub-group B (reference group) 28 persons were qualified. Among the participants, a questionnaire was spread, prepared for the needs of the survey, to be filled in. For testing the sequence of stimulations, the measurements were used which had been obtained from the sEMG record during the Prone Hip Extension (PHE )Test.*
**Results:** *The results obtained during the examination of the muscles recruitment pattern in PHE test showed a changed sequence of muscles activation in the Patients from sub-group A vs. these from sub-group B. The results of chi-square test ($\chi^2$) confirmed the statistically significant dependence: the persons with pain symptoms in the lumbar spine statistically less frequently showed the correct sequence of muscles engagement: $\chi^2$=5.05, p=0.041, R= - 0.59 (strong negative dependence).*
**Conclusions:** *Changes in the pattern of muscles recruitment during the hip joint extension lead to overloads in the lumbosciatic area, consequently causing pain in the lumbar section. Superficial electromyography, because of the possibility of obtaining the quantitative outcome, is a useful method of evaluating muscles performance.*

***Key words:***
*The Janda test, Prone Hip Extension Test, PHE, sEMG, LBP, pain in the lower part of back*

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## Introduction

Spinal pain syndromes are the most common cause of patient's visits at doctor's of various specialisations. The statistics of patients visiting the physiotherapists is also impressive, nearly 80% of the cases are spinal pain syndrome. Large majority of them pertain to the lower, lumbar section [1], which in scientific literature is referred to as LBP (low back pain) [2]. Examinations, using Magnetic Resonance or 3D Computer Tomography for differential diagnosis in case of LBP, provide clear information about the morphological condition of the examined structures. Not always, though, the imaging examination is sufficient in clinical evaluation of the patient, particularly in cases where there are no definite structural changes [3]. In situations like the one described above, in order to make a correct diagnosis, other possible causes of the ailment are investigated. Scientific reports indicate that pain in the lumbar spine is frequently accompanied by muscle imbalance [4]. This pertains to the posterior group of the thigh, the gluteal muscles and the erector muscle in the lumbar section [5, 6, 7]. From the observations of selected groups of muscles in the lumbo-gluteo-sciatic section it arises that the sequence of stimulations for work is incorrect in comparison to the correct sequence pattern of these muscle recruitment, presented by Vladimir Janda [8]. For the evaluation of the work of a single muscle, as well as a whole group of muscles, the kinesiological superficial (fine wire) electromyography (sEMG) is used [9]. Due to the omnipresent problem of complaints concerning the lumbar spinal pain, the priority is detailed, comprehensive diagnostics, which would allow to define precisely the cause of pain, and consequently to be able to take a targeted therapy [10]. Using additional modern diagnostic methods seems helpful, and among them also sEMG, which allows to evaluate the muscle for the needs of physiotherapy [9].

## Material and methods

Subgroup A consisted of 33 persons aged 20 to 30 y.o., average age was 25 y.o. (+/- 6 years). There were 21 women and 12 men in this subgroup. In (reference) subgroup B, the examination covered 28 persons aged 20 - 35 years old, the average age was 26 years old (+/- 8 years), and in this number 17 women and 11 men. The selection for the subgroups was non-random and took in account the criteria of inclusion and exclusion. The inclusion criterion referred to people with pain complains in lumbar spine or without this pain. The following persons were excluded from the study: with congenital, structural, post-trauma or post-surgery defects of the hip joint and spine, with discopathy in the lumbar spine, atrophy of the muscles within the trunk and lower limbs developed after a trauma or arising from inactivity, with endoprostheses in lower limbs, pregnant women, people walking with crutches, with defects of the central or peripheral nervous system, and in case of lacking consent for the examination. Examinations of the patients took place in the Institute of Physiotherapy at Gdańsk Medical University and were carried out by the same physiotherapist. The measurements of muscle stimulation sequences were taken with a four-channel devise used for signal recording in sEMG examination. Data recording and analysis was done on a computer with installed software compatible with MyoTrace 400 device, MyoResearch Master Edition from Noraxon, whose Polish distributor is PHU Technomex Sp. z o.o. The examined person during the measurements was lying face-down on a therapeutic bed.

Electrodes location: 1st wire – 2 electrodes on the extensor muscle in lumbar spine, at the level of L3; 2nd wire - 2 electrodes on the extensor muscle in lumbar spine, at the level of L3; 3rd wire – gluteus maximus muscle; 4th wire – muscles of the posterior group of the thigh;  reference electrode – the ala of ilium bone [Fig. 1].

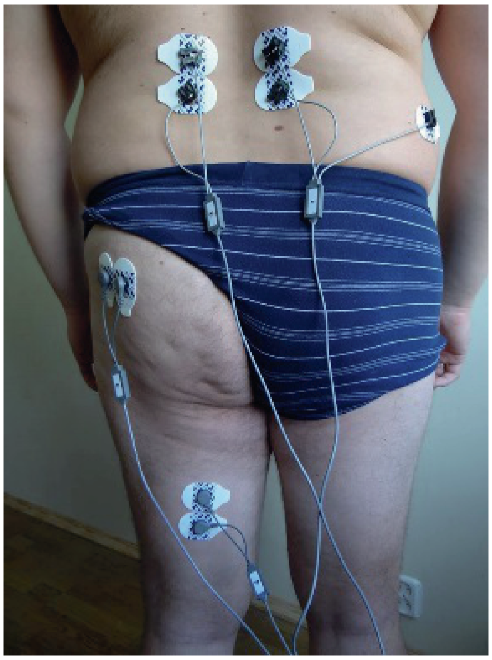

**Fig. 1. Arrangement of the sensing electrodes. (Own archive)**

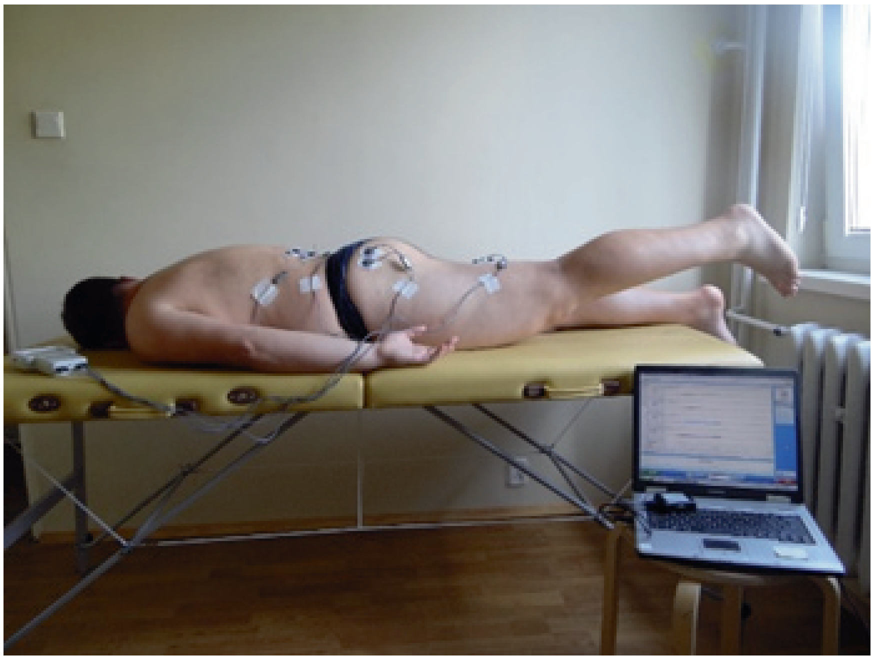

**Fig. 2. The sEMG measurements during extension in the hip joint (own archive)**

The subject matter of the study was Prone Hip Extension Test (PHE) [11]. The patient's task was to perform a slow, slight extension in the hip joint while maintaining the knee joint extended. During the examination, the range of extension or the pelvis stabilisation were irrelevant [Fig. 2].

Before the examination, the examined person was instructed about its principles and then a test measurement was taken. For the analysis, five measurements were taken. All measurements were taken in the morning to minimise the daily bioelectric variability of the muscles. The sEMG test was consistent with the directives of the SENIAM project for this type of research [12]. Before taking the measurements, all examined person were informed about the purpose and course of the examination and their signed consent for this examination to be performed on them. The obtained data were qualitative variables. The distribution of the variables deviated from normal, and this determined the use of non-parametric tests. To find the statistically relevant association of variables, the $\chi^2$ (chi-square) test was used. To determine the strength of relationship, Cramer's V coefficient or Pearson contingency coefficient were used. In all tests, the statistically relevant association was assumed at the level of p ≤0,05. For performing the statistical analysis, software Statistica 10 was applied.

## Results

The results obtained are presented below as the answers to the questions put in the research.
Below, there are presented the most frequent patterns of muscles recruitment during extension in the hip joint in both subgroups, and their correlation wit the pain symptoms in the lumbar spine [Tables 1-2, Fig. 3-4].

**Table 1. Schemes of configurations of muscles recruitment patterns during PHE test for subgroup A.**

| System 1 | System 2 | System 3 | System 4 | Other System |
|---|---|---|---|---|
| 1.Erector spinae (mES)<br>2. Ischio-shin group (mmI-SG)<br>3. gluteus maximus (mGM) | 1. Ischio-shin group<br>2. gluteus maximus<br>3. Erector spinae | 1. Ischio-shin group<br>2. Erector spinae<br>3. gluteus maximus | 1. Erector spinae (ipsilaterally)<br>2. Ischio-shin group<br>3. Erector spinae (contralaterally)<br>4. gluteus maximus | Other combinations of patterns |

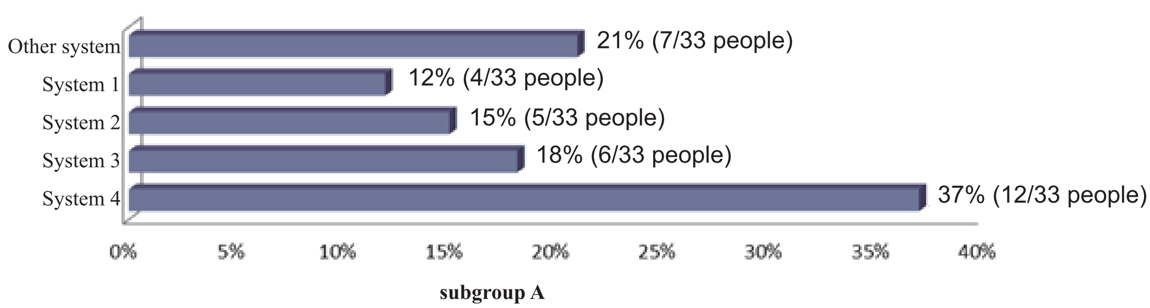


**Fig 3. The percentage juxtaposition of muscles recruitment patterns during PHE test for Subgroup A**

**Tab. 2. Configuration schemes of muscles recruitment patterns during PHE test for Subgroup B**

| System 1 | System 2 | System 3 | System 4 | Other System |
|---|---|---|---|---|
| 1. gluteus maximus | 1. Ischio-shin group | 1. Ischio-shin group | 1. gluteus maximus | Other combinations of patterns |
| 2. Ischio-shin group | 2. gluteus maximus | 2. Erector spinae | 2. Erector spinae | |
| 3. Erector spinae | 3. Erector spinae | 3. gluteus maximus | 3. Ischio-shin group | |

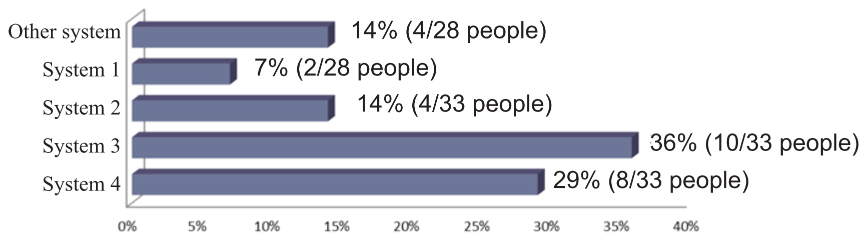


**Fig. 4. The percentage juxtaposition of muscles recruitment patterns during PHE test for subgroup B**

The below published analysis [Fig. 5] presents muscles recruitment patterns in PHE test in persons examined in accordance with the correct recruitment pattern acc. to Janda. The model pattern referred to the following sequence of stimulations: gluteus maximus muscle (mPW), ischio-shin muscles (mmKG), erector spinae of the lumbar spine – ipsilaterally (mPGi), erector spinae of the lumbar spine – contralaterally (mPGk) [8, 13].

The most frequent recruitment pattern in Subgroup A was initiation of the movement by activating erector spinae in the lumbar spine, which occurred in 49% of the examined persons (n= 16). While in subgroup B it was observed that the movement was initiated by the ischio-shin group in 50% of the examined (n=14) pr by gluteus maximus muscle in 36% of the examined persons (n= 10). The results of $\chi^2$ test confirmed the statistically relevant dependence; the persons with pain symptoms in lumbar spine statistically showed the correct sequence of muscles engagement less frequently: $\chi^2$ =5.05, p=0.041, R=-0.59, strong negative dependence. The analysis presented below [Fig. 6] shows the muscle recruitment patterns in PHE test in the examined persons, which follow the incorrect recruitment standard, acc. to Janda. A model, incor-

rect, standard indicated the following sequence of stimulations: mPGi, mPGk, mPW, mmKG, [8, 13].
The pattern of recruitment during the hip joint extension, predisposing mostly to the induction of lumbar pain is when the movement is started by the erector spinae in lumbar spine. Such pattern was observed in 49% (n= 16) of Subgroup A. The $\chi^2$ test results confirmed a statistically relevant strong dependence. Persons with pain symptoms in lumbar spine statistically more often engaged the muscles in the following sequence: $\chi^2$ = 11.4, p=0.0007, R=77, strong positive correlation.

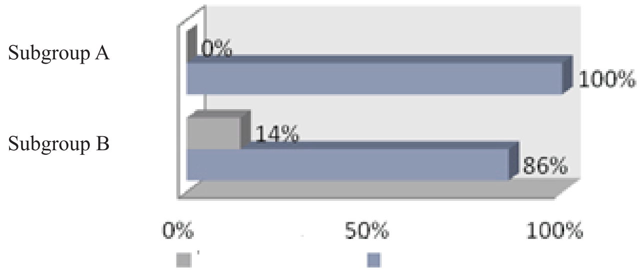


**Fig. 5. The percentage structure of the correct pattern occurrence in both examined subgroups (Subgroup A vs. Subgroup B)**

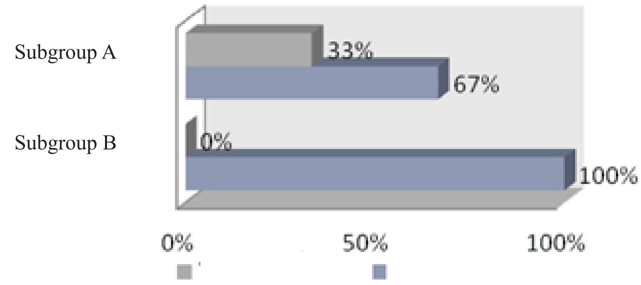


**Fig. 6. The percentage structure of the incorrect standard occurrence in both examined subgroups (Subgroup A vs. Subgroup B)**

## Discussion

Many cases of back pain deemed idiopathic until recently, presently are seen not only as a kind of disorder and dysfunction of local character, but also as disorders resulting from changes in the whole musculoskeletal system [9, 14, 15, 16]. Norris and co. (1995) suggested that the changes in movement patterns (MP) and motor control (MK) play a fundamental role in the development of musculoskeletal dysfunctions [15]. It should be noted that disturbance in the pattern of muscle balance, repeated everyday many a time in functional movement, make the way for the incorrect MP to the central nervous system. Unless the incorrect afferentation is interrupted, it comes to the fixation of an incorrect MK. Janda states that the changes in the correct pattern of muscle recruitment for the hip joint extension cause disorders of the lumbopelvic rhythm. This condition leads to overload and pain in the lumbar spine. A disorder of gluteus maximus is of special significance here [8]. Chaitow claims that muscle pain results from tension and shortening the structures within the muscle, related to the local exposure of the tissues to an extensive load. Furthermore, Chaitow confirms Janda's observations that weakening of mGM causes extensive tension, and, at later stage, the shortening of erector spinae muscle (mES) in lumbar spine, leading to this area's overload, a consequence of which is pain [5]. Guimaraes and co. in 2010 presented a study in which they confirmed results obtained by Janda and other authors, indicating one correct activation sequence of the muscles extending the hip joint in PHE test. These researchers had found that in spinal pain syndromes this pattern is essentially changed. Moreover, these authors noted that there is a certain separate group of people deviating from the assumed scheme, manifesting a different PHE movement pattern [6]. Furthermore, in 2012 Tateuchi and co. carried out research on 16 people. They proved that a change in the PHE pattern results in lack of stabilisation in the pelvis. A consequence of this is a pathokinetic increase of the pelvis anteversion and lumbar lordosis [7]. Similar results were obtained by Lewis in 2009. He acknowledged that a disorder in the PHE movement pattern where an earlier activation of mES or mmI-SG) occurs, causes a delay in mGM activation [17]. Himmelreich and co. in 2008 published a study in which they report, like the authors mentioned earlier, that idiopathic loin pain is frequently correlated with musculoskeletal disorders and imbalance of the muscles stabilising the pelvis, particularly the muscles extending the hip joint. Moreover, they stated that weakening of and disorder in mGM nerve-muscle control is significant not only for the pelvis stabilisation but also for the distal joints of the lower limb. The EMG examinations carried out by them in Patients with LBP point to an increased fatigability of this muscle while walking, in comparison to the reference group without pain symptoms [18, 19]. Leinonen and co. in 2000; they also believe that a weakened mGM is responsible for disturbing the correct lumbopelvic rhythm. They carried out research on 19 women with loin pain. It appeared that in these examined persons, mPW joins the movement later and the time of its operation is shorter in comparison to the reference group. Whereas, traces of overreactivity were observed in mES of lumbar section, which joined the movement before mPW. Additionally they stated that mES should not demonstrate activity at the beginning of extending movement in the hip joint, even while lifting a weight of up to 28.5kg [20, 21]. Singh and co. in 2005 r. recognised that tensions and misbalance within mES are responsible for chronic lumbar pains occurrence [22]. Bullock-Saxton (1993), found that frequently in chronic pains a dysfunction of mGM occurs, but in the process of physiotherapy (rehabilitation), including this muscle into the therapy is often neglected. What is more, according to Bullock-Saxton, an attitude which includes the motor regulation and the quality of performing the motor activities into the clinical practice, seems to be completely neglected by most clinicists [16]. The recruitment sequence identified by Janda has been confirmed by several other researchers. Not all of them, though, agree with the PHE muscle recruitment pattern proposed by Janda. Comerford (2001) believes that the movement of hip extension is initiated through flexing the mmI-SG [23]. Lewis claims that mGM flaxes immediately after or simultaneously with mmI-SG [17]. Whereas, according to Lehman and co. (2004), one universal muscle recruitment pattern does not exist, either in persons with pain symptoms or without them. According to this author, the recruitment pattern depends on individual patterns of nervous-muscular play [7, 24]. The same point of view is shared by Pierce and Lee, who carried out research in 1990 on 12 healthy persons. Each of them performed 30 extending movements in the hip joint. The time of joining-in was measured with the use of sEMG. In this study, no statistically significant repeating rule of muscle recruitment sequence was proven. According to Pierce and Lee, this means that in Patients with lumbar pain we cannot talk about changed pattern of muscle recruitment as a cause of pain [24]. While Roussel (2007) is of the opinion that with the help of standardised tests the Patients with lumbar pain should be classified and then divided into subgroups according to changed motor patterns, in order to choose an appropriate treatment strategy aimed at restoring the correct motor control [25]. In spite of the divergence in establishing the correct pattern of muscle recruitment during the hip joint extension, all authors agree to the fact that erector spinae, in correct biomechanical conditions, should not initiate the movement but only support it in the final range. This causes a relative increase of the mobility range by anterior pelvic tilt and by increasing the lumbar lordosis. Whereas, in situation when erector spinae takes control of the movement, it results in disturbing the motor control and, in consequence, to muscle imbalance and pain complaints [5]. Authors of this study obtained a confirmation of the observations carried out by Janda. In patients with pain symptoms, statistically more frequent incorrect sequence of stimulations initiated by erector spinae occurred in the performed PHU test, which was proven in 49% (16/33) of the examined persons. Recruitment for activation by the ischio-shin group took place in 33% (11/32)of the examined patients. In the surveyed Subgroup A, the activation by gluteus maximus muscle did not occur. In subgroup B, the pattern presented by Janda as a model one, proven in 36% (10/28) of the examined persons. Although, most often, an anticipatory activation during the performed test was shown by the ischio-shin group, which concerned 50% (14/28) of the examined. The above observations are consistent with the results of other authors' research. The presented results of observations constitute a pilot study and require observations of a larger population of patients with randomised trial. Very often, the method of measuring muscles functions which is used in scientific research is sEMG, as a tool which is simple, objective and non-invasive, but not free from defects, though. The integrity and reliability of the measurement and the results of sEMG depend on appropriate methodology of the research and on correct processing of the obtained data. Normalisation Timing (OnSet) and MVC are the most common normalisations evaluating the motor patterns with the use of sEMG in scientific research [12, 26, 27]. The convenience of sEMG is collecting the data concerning muscle performance, both in statistic figures and in various dynamic motor tasks [9]. Electromyography has won acknowledgement among numerous researchers engaged in mechanics and pathomechanics (Janda, Hodges, Comerford, Vogt). Also authors of this study used superficial electromyography as a method typical for research in this field.

## Conclusions

1. A change of the stimulation sequence in muscle recruitment during the hip joint extension contributes to imbalance of the muscles in the lumbosciatic area and may be a possible cause of pain arising in the lumbar spine.
2. The results have proven a statistically relevant dependence. Persons with LBP symptoms statistically less frequently demonstrated correct sequence of muscles engagement in PHE-test.
3. The most frequent pattern of recruitment occurring in Subgroup A was initiating the movement through the activation of erector spinae muscle in lumbar spine. While in subgroup B, movement initiation by the ischio-shin group was observed.
4. A recruitment pattern during the hip joint extension predisposing mostly to the induction of lumbar pain was when the movement was started by the erector spinae in lumbar spine.
5. Superficial electromyography is a useful diagnostic tool in supplementary examination. It may serve for evaluating the tension, function and coactivity of muscles, enabling comparing the obtained results with a model pattern assumed by Janda.

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