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Disbalance and fatigue of the spinal extensors as one of the causes of the overload disease of the lumbar spine

JOANNA ZYZNAWSKA[1]*, GRZEGORZ FRANKOWSKI[1], EWA WODKA-NATKANIEC[2],
DARIA KOŁOMAŃSKA[1], KAMILA BOCZOŃ[1], MAŁGORZATA KULESA-MROWIECKA[1]

[1] Department of Physiotherapy, Faculty of Health Sciences,
Jagiellonian University Medical College, Kraków, Poland.
[2] Department of Orthopaedics and Physiotherapy, Faculty of Health Sciences,
Jagiellonian University Medical College, Kraków, Poland.

Purpose: The aim of the study was to find out whether among young active people – the future healthcare professionals – there is a risk of developing lumbar spine overload disease depending on the occurrence of the disbalance of paravertebral muscles and to assess the fatigue of the examined muscles depending on the body position during the work. *Methods*: The study involved 50 randomly selected students of physiotherapy and emergency medical services of a mean age of 21 years. The surface electromyography (sEMG) was used to measure the activity level of spinal extensors of the cervical and lumbar spine. The statistical analysis of the results was made using the RStudio software. *Results*: Study shows that the majority of the examined students had a slight asymmetry between the bioelectric activity of the right- and left-side dorsal extensor bands, both in the cervical and lumbar sections (right side 118.6 Hz / left side 115.7 Hz / extension and 98.6 Hz / 95.5 Hz /flexion). Depending on the position, significant fatigue in the examined muscles was found ($p < 0.05$). *Conclusions*: The experiment showed a slight disbalance in the average bioelectromyographic activity in the area of spinal extensors during their symmetrical work. This can be the basis for the development of the overload disease in the weaker muscle parts, which generate more fatigue during the activity. It is worth to carry out similar tests in a much greater group, taking the longer-lasting muscular effort into account.

Key words: *fatigue, sEMG, muscular disbalance, extensor muscle, overload disease*

1. Introduction

Spinal extensors are a very important group of postural stabilizers. They are responsible for movement and protection of the spine during important functional activities such as bending, lifting, load-carrying, standing and many others. Because of such importance, their motion should be full and unimpaired, otherwise pain may appear. Spinal extensors consist of two symmetrical bands arranged on either side of the spine. These are (from the centre in the lateral direction): the spinalis, the longest muscle of the torso and the iliocostalis [2]. Tension asymmetry, or muscular disbalance of this muscle group may adversely affect soft tissues and other spine structures leading to pathology. Disbalance results from the disturbance of a correct muscle balance. The main reason for the formation of muscular disbalance is asymmetrical body work or forced, incorrect position associated with the shift of the centre of gravity in the body. It can also be a result of a postural defect or unilateral injury within a given muscle group [4].

The study looks at spinal extensors of young, active people – future physiotherapists and paramedics studying at the Faculty of Health Sciences of the Jagiellonian University Medical College: on what is the level of their muscle fatigue depending on an indi-

* Corresponding author: Joanna Zyznawska, Department of Physiotherapy, Faculty of Health Sciences, Jagiellonian University Medical College, Medyczna 9, 30-688 Kraków, Poland. E-mail: joanna.zyznawska@uj.edu.pl

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vidual working position and whether both muscle bands work symmetrically during selected efforts if the starting position does not compel asymmetry. The aim was to find out whether in the case of young, healthy subjects who experience fatigue during work, e.g., as a result of a weakened strength or muscle endurance, only one part of less well-prepared muscles may overload, which, in the long term, will result in a full-fledged pathology and may constitute the basis for the development of a pathological disbalance. The study group included subjects without diagnosed postural disorders, without reported pain and no trauma incidents.

Healthcare professionals (e.g., physiotherapists, paramedics, nurses) as a result of working in a monotonous position and because of the need to deal with heavy loads (lifting patients, heavy equipment, etc.) are often subjected to excessive efforts, resulting in overload syndrome and pain [14]. Therefore, it will be important to learn the various causes of functional disorders and to implement adequate principles of prevention and work ergonomics.

The primary goal of the study was to find out whether the future healthcare professionals, mainly students of physiotherapy and emergency medical services, experience disbalance of paravertebral muscles.

The secondary goal was to assess the fatigue of the examined muscle in different positions and then to compare the parameters from both sides (right and left) to check whether both bands work symmetrically and generate the same fatigue. An additional goal was to analyse whether this situation could be a risk factor for the development of the lumbar spine overload disease and, subsequently, the lumbar pain.

2. Materials and methods

The study involved 50 randomly selected students of physiotherapy and paramedic services of a mean age of 20.9 (±1.4). Participants qualified for the study were students who appeared in the building of the Department of Physiotherapy on the day of the research, regardless of the purpose of their visit. The group included 43 women (86%) in the age bracket from 19 to 25 (average 21 ± 1.4) and 7 men (14%) aged 19 to 22 (average 20.4 ± 0.9). The height of all students ranged from 161 cm to 192 cm (average 169.4 ± 7.7), and weight from 50 to 99 kg (average 63.8 ± 10.8). The inclusion criteria were: lack of posture alignments, active lifestyle, fitness and lack of medical contraindications to participate in physical education classes in accordance with the program of the Faculty of Health Sciences of the Jagiellonian University Medical College and a consent for participation. The exclusion criteria included: fresh, unhealed injuries, diagnosed postural defects, significant pain, general poor health and well-being as well as a lack of consent to participate in the research.

The surface electromyography (sEMG) TeleMayo G device with the MyoResearch software, Noraxon MT400, USA was used to measure the activity level of the right and left spinal extensors of the cervical and lumbar spine. The skin in places where the electrodes were applied was cleaned with alcohol. The research applied the SENIAM project guidelines [12]. Each test was preceded by a resting measurement. Measurements of muscle activity in the cervical and lumbar segments of the spine were carried out in isometric fatigue tests which are considered to be reliable [14]. The tests were carried out three times.

The first exercise aimed at the cervical spine started from a supine position with arms along the torso. In order to obtain isometric activity of the examined muscles, the headrest was lowered and the subject was instructed to maintain a horizontal position for 30 seconds (measurement 1).

The second exercise of the cervical spine started with a subject sitting in a chair at a desk, the head remained in the torso line with forearms bent in the elbows arranged on the desk top. The subject looked at the desk as if reading a newspaper, after which they were instructed to bend the neck within 30 degrees and remain in the position motionlessly for 30 seconds. The flexion range was determined using an inclinometer. In this way eccentric isometric activity of the examined muscles was obtained (measurement 2).

As for the lumbar spine, the first test consisted of the extension of the torso and upholding the lumbar spine in the 0-degree position, from the initial supine position on the couch lowered at the 60-degree angle. Upper limbs were bent at the elbows, the forehead resting on the hands. From this position the torso was extended and the isometric contraction phase followed. The subject straightened the torso so that the head, shoulders and the entire spine were in a straight line with the lower limbs and kept in this position for 30 seconds (measurement 3).

The second test for the lumbar spine commenced in the starting position facing the couch. Upper limbs laid loosely along the torso, legs hip-width, the trunk straight. Subsequently, the subject was asked to bend to an angle of 30 degrees with an underhold on the edge of the couch. During the test, the couch constituted a resistance for the subject, therefore creating the isometric activity phase. The height of the couch was adjusted to the height of the subject. The test lasted 30 seconds. After 30 seconds the grip was released and the subject straightened up. The test was designed to simulate a forced functional position, e.g., during the work of a physiotherapist or nurse with a patient lying in bed (measurement 4).

The comparative analysis of sEMG amplitudes ("is the muscle more or less active") was used to assess the parameters depending on different contraction conditions [3]. Measurement reports created for each subject included a mean of activity of right and left spinal extensors in the first and thirtieth second of its work (start-end ratio) in subsequent tests.

The statistical analysis of the results was made using the RStudio software. Accordance to normal distribution was assessed with Shapiro–Wilk test. Compatibility was found, therefore parametric Student *t*-tests was used. The results were considered statistically significant for $p < 0.05$. In addition, all participants were asked to provide information if they experienced pain in the examined spine region and data regarding their everyday physical activity.

3. Results

The mean frequency of cervical muscle contraction

In measurement 1, during the isometric extension, the mean frequency of the right cervical extensor in the first second of contraction was 76.3 Hz (±18.4) and the left extensor 79.4 Hz (±16.3). In the thirtieth second of activity, the average frequency for the right cervical extensor was 77.0 Hz (±19.4) while for the left it was 78.6 Hz (±14.0).

In measurement 2, the flexion test, the mean right-side muscle frequency in the first second of the contraction was 68.6 Hz (±11.0) and the left-side 71.0 Hz (±12.3).

The average contraction value of the right cervical extensor in the thirtieth second the test was 69.9 Hz (±13.0), while for the left-side muscle it was 69.3 Hz (±9.5).

Cervical muscle fatigue [%]

Bilateral muscular fatigue was determined based on the ratio of the average muscle frequency in the first and the thirtieth seconds of the contraction. Measurement 1: for the right cervical extensor in the extension test an average fatigue was: +1.9%, and for the left extensor –0.4%. Measurement 2: for the right cervical extensor during the flexion test the average fatigue value was +3.5%, while on the left side it was +0.9%. Post-fatigue values did not show a statistical significance of $p > 0.05$.

The mean frequency of lumbar muscle contraction

Similar parameters were calculated for the lumbar spine. In measurement 3, during the extension, the mean mobile frequency of the right lumbar extensor in the first second of the contraction was 118.6 Hz (±23.0), on the left side it amounted to 115.7 Hz (±20.4). At the thirtieth second, the mean mobile frequency of the right lumbar extensor was 98.6 Hz (±18.7) while the left-side frequency was 95.5 Hz (±18.7) (Fig. 1).

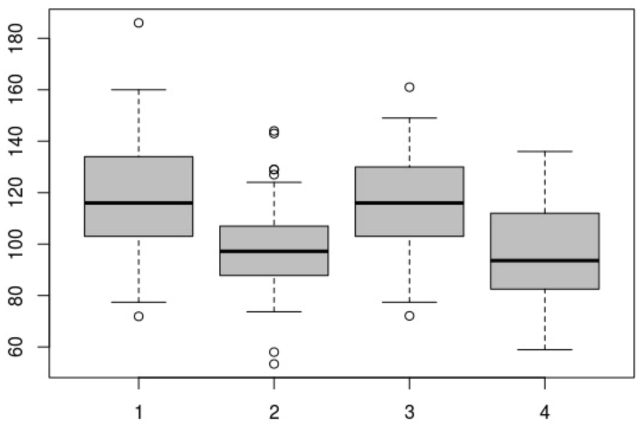

Fig. 1. Fatigue values of the left and right lumbar extensor during the extension test: 1 – right lumbar extensor, first second of extension – mean 118.6 Hz (±23.0); 2 – right lumbar extensor, thirtieth second of extension – mean 98.6 Hz (±18.7); 3 – left lumbar extensor, first second of extension – mean 115.7 Hz (±20.4); 4 – left lumbar extensor, thirtieth second of extension – mean 95.5 Hz (±18.7)

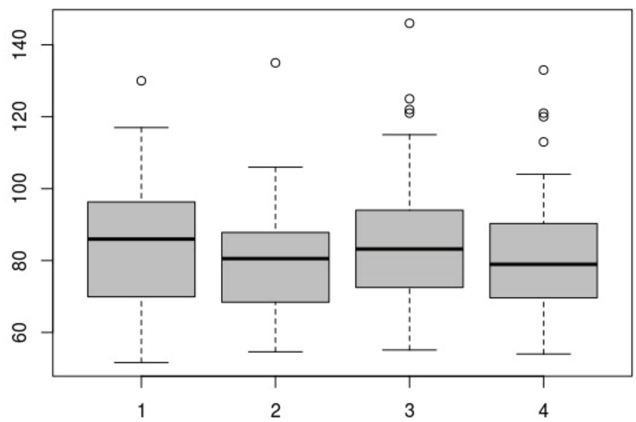

Fig. 2. Fatigue values of the left and right lumbar extensor during the flexion test: 1 – right lumbar extensor, first second of flexion – mean 84.6 Hz (±16.4); 2 – right lumbar extensor, thirtieth second of flexion – mean 80.7 Hz (±15.0); 3 – left lumbar extensor, first second of flexion – mean 85.2 Hz (±14.5); 4 – left lumbar extensor, thirtieth second of flexion – mean 82.0 Hz (±17.3)

In measurement 4, the test for enduring flexion, the average frequency of the right extensor in the first second of the contraction was 84.6 Hz (±16.4), while the left-side value amounted to 85.2 Hz (±14.5). In the thirtieth second the results were: right-side extensor 80.7 Hz (±15.0), left–side 82.0 Hz (±17.3) (Fig. 2).

A slight difference between the bioelectric activity of the right- and left-side extensor in both tests indicates a slight disbalance, however the result is not statistically significant.

Lumbar muscle fatigue [%]

The correlation between the average muscle frequency of the lumbar extensor in the thirtieth and the first second of their contraction was analysed. In measurement 3, the extension test, the following results were obtained: the average right-side fatigue: –16.0%, left-side: –17.4%. In measurement 4, the flexion test: –4.6% on the right, –3.7% on the left. A significance level of $p < 0.05$ was obtained for the lumbar fatigue measurement values.

A very small asymmetry of the right and left cervical bands and slight bilateral fatigue was observed in the mean frequency values of the sEMG record for the thirtieth and the first second of activity. As for the lumbar region, similar differences were observed for both sides, however the values were higher than in the cervical area, which confirms the tendency to greater fatigue of the weaker band at the end of the performed activity (Table 1). The results of lumbar tests clearly show a greater fatigue during extension.

Table 1. Average frequencies in the electromyographic record for All the subjects were asked to record any occurrence of pain in the examined sections of the spine. No one declared a chronic or temporary pain that would significantly affect their level of activity and limit their participation in physical education classes. Therefore, the subjects can be considered healthy individuals who do not suffer from spinal pain. Forty seven subjects described themselves as physically active.

4. Discussion

The presented results indicate that there is a potential risk of spinal overload disease in future physiotherapists. A number of authors embrace a similar research into risk factors, frequency and prevention of spinal injuries in this professional group [2], [6], [11], [13]. Our research may respond to the search of the causes of pain in the musculoskeletal system of the spine.

Examination on the activity of the spinal extensors shows that in the majority of subjects there was a slight

Table 1. Average frequencies in the electromyographic record for the right and left band of the test sections relative to each other

Cervical extension test			
Side \ Time	1 s	30 s	difference/fatigue
Right	76.3 Hz	77.0 Hz	<0.7 (+) / +1.9%
Left	79.4 Hz	78.6 Hz	>0.8 (–) / –0.4%
Cervical flexion test			
Side \ Time	1 s	30 s	difference/fatigue
Right	68.6 Hz	69.9 Hz	<1.3 (+) / +3.5%
Left	71.0 Hz	69.3 Hz	>0.7 (–) / –0.9%
Lumbar extension test			
Side \ Time	1 s	30 s	difference/fatigue
Right	118.6 Hz	98.6 Hz	>20.0 (–) / –16.0%
Left	115.7 Hz	95.5 Hz	>20.2 (–) / –17.4%
Lumbar flexion test			
Side \ Time	1 s	30 s	difference / fatigue
Right	84.6 Hz	80.7 Hz	>3.9 (–) / –4.6%
Left	85.2 Hz	82.0 Hz	>3.2 (–) / –3.7%

disbalance between the right and left bands during activity, both in the cervical and lumbar sections. The analysed values indicate that the examined muscles do not work with the same frequency on both sides during isometric contraction. The lack of the required level of statistical significance may result from too small size of the examined group, too short duration of the contraction or young age and a relatively high level of motor skills of the subjects, as declared by the majority. It is worth noting that although the differences in the tensions on both sides were small, in all the respondents the initially stronger side completed the test with a smaller difference in average frequency, which indicates less fatigue on this side, and the reverse on the weaker side. In subsequent studies of this type, it seems reasonable to examine whether these parameters will maintain a similar tendency with longer and heavier physical activity.

The fatigue analysis of the examined muscles indicate that in accordance with the law of ergonomics, the greater the leverage, the greater the fatigue [15]. The cervical spine fatigue test did not show considerable differences in the obtained values. During the extension of the right band, it was shown that apparently the muscles not only did not get tired, but the frequency of their contraction increased at the end of the activity which would indicate that they improved their efficiency. In reality, however, it is not possible. This result may imply that the signal from this site was possibly disturbed by a signal from other muscle groups, which is associated with the specific area of the study (cervical spine) [4] or the compensation due to a faster fatigue of the examined band. Other authors confirm the existence of the phenomenon of the automatic occurrence of adaptation mechanisms, i.e., the involvement of additional muscle groups [1]. It is worth to further analyse if muscles require assistance with such a small and short-term isometric effort, can it signify their weakening or only a high adaptive ability?

Based on the analysis of the disbalance of the lumbar extensor, it was observed that the lumbar fatigue is definitely more noticeable compared to the cervical area. In the flexion test, the subjects had to overcome more strength in the form of the couch, but they operated on a shorter lever. In the case of an extension test, the muscle activity was performed with a long lever. The study shows that with a simple test, without any additional resistance except the force of gravity but with a long lever, the muscle experiences greater fatigue than when overcoming a significant weight, but on a shorter lever. A number of authors [15] confirm the high importance of the ergonomics of work in the health care sector. The test positions in this study were specifically selected to refer to the extremely different situations that can be encountered while performing medical duties. The closer the patient and the hospital bed/rehabilitation table, as well as the greater the ability to perform work in which the upper limbs are closer to the torso, the muscular effort is smaller and overload is avoided despite the increasing resistance. This is an important evidence, since in the case of health care professionals the lumbar spine is often overloaded and may even lead to occupational disease – chronic spinal pain due [14]. In the case of a prolonged work, definitely longer than in the conducted study, in a forced position over a hospital bed, an ever increasing muscle fatigue may lead to augmented asymmetry of tension and disbalance, and, in further stage, to the development of serious musculoskeletal disorders.

Nicolas Mazis [5] investigated the effect of non-specific lumbar spine pain on the activity of the extensor and confirmed the importance of spinal pain in the occurrence of lumbar extensor asymmetry. Similarly, in 2006, Tobias Renkawitz, Daniel Boluki and Joachim Grifka carried out a study confirming the association between the occurrence of lumbar spine pain with the disbalance of the spinal extensors [10]. In both presented studies, the authors obtained a statistically significant relationship between disbalance of the spinal extensor and lumbar pain. Therefore, it can be concluded that when additional circumstances overlap, such as pain, chronic fatigue and functional changes, this may amount to the occurrence of the overload disease. In turn, Ściegenna et al. [4] examined a group of professionally active physiotherapists and confirmed that the lumbar pain is frequent and related to the specificity of work. These results are confirmed by Iqbal and Alghadir [2] who indicate the importance of ergonomics and the application of appropriate techniques while conducting physiotherapy with patients.

By exploring work techniques and their loads we can partly refer to our results. Our research showed that at the end of the isometric contraction in the cervical area there was a change in the average frequency difference in the electromyography record as part of the asymmetry of the right and left band in relation to each other. This may prove that the activity of a weaker band in the cervical area was replaced by stronger ones, which, in turn, resulted in a greater effort and fatigue at the end of the task. Such situation in a prolonged activity may lead to asymmetric overload. Analysing the results of the test in the lumbar region, it was also noticed that the weaker band experienced a greater fatigue. In such case, with a prolonged effort, the asymmetric overload in the area may increase.

It should be taken into account that the study maintained symmetrical exercise conditions, it was done by young and healthy individuals who did not report chronic pain. All subjects declared a relatively frequent participation in various physical activities, for example, attending physical education classes in accordance with the curriculum. The experiment should be treated as a pilot study, and, in order to examine in a more precise way the degree of occurrence of disbalance and fatigue and their mutual dependence, it is worth to carry out a research in a much greater group. The duration of contraction may not seem sufficient to obtain statistically significant values when recorded from young, healthy and athletic subjects. The similar test for a longer-lasting muscular effort seems justified. However, currently a strong emphasis should be placed on the work ergonomics in the health care sector, as well as on good physical preparation of future professionals performing static work in a forced, uniform position. This is closely related to the creation of higher education curricula, especially for such majors as physiotherapy and emergency medicine, where the physical education together with other programs promoting physical activity become indispensable in preparation for the future occupation [12]. During the classes, it is worth paying particular attention to the general development training in terms of symmetrical involvement of all muscle groups.

The analysis and an in-depth understanding of processes related to muscular fatigue are, in turn, of great importance when arranging workplaces. Their assessment, both at the stage of designing and subsequent use, will help to determine optimal conditions for professional activities.

5. Conclusions

1. In the studied group of young students there is a slight disbalance in the average bioelectromyographic activity in the area of spinal extensors.
2. The study of spinal muscle fatigue in the sEMG record shows that in line with the law of physics, the greater the leverage in the activity performed, the more the relevant parameter increases.
3. When maintaining the ergonomic principles of the workplace, despite a greater effort/resistance to overcome, a smaller muscle fatigue can be obtained.
4. Even a small muscular disbalance during a greater effort can lead to overload within more intensely utilised motor organs.
5. It is worth performing similar tests on a larger group employing longer-lasting muscle efforts.

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