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# IMPACT OF STRENGTHENING OF THE ERECTOR SPINAE MUSCLE ON THE VALUES OF LOADS OF THE MUSKULOSKELETAL SYSTEM IN THE LUMBAR SPINE SECTION

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**Abstract:** *This work aimed to determine resultant changes of reactions in the lumbar spine section (L5-Sacrum) influenced by strengthening of the erector spinae (spinal erectors) muscle. Identification of the loads of the musculoskeletal system was conducted by means of a mathematical model of the human body created in the Anybody Modeling System environment. The results of the measurements of kinematics were used as input data. Strengthening of the muscle was simulated by increasing a maximum isometric force which could be generated by a single muscle by means of increasing its physiological cross section. On the basis of the performed calculations, it was observed that the increase in the cross section of the transverse erector spinae muscle causes the increase of reactions in the L5-Sacrum joint, simultaneously lowering the strength of the transverse abdominal muscle and the value of the intra-abdominal pressure. Conclusions resulting from this research may be used in physiotherapeutic practice for the selection of exercises which aim to reduce pain ailments in the lumbar spine section.*

**Keywords: Anybody Modeling System, Erector spinae muscles, Mathematical modeling, Lumbar spine.**

## 1. Introduction

Pains occurring in the lower part of the back are one of the most common chronic ailments. They cause considerable limitations to movement and make it impossible to maintain a correct body posture. Pain in the lower section of the spine is commonly caused by weak paraspinal muscles, i.e. the muscles stabilizing the spine. The stabilization of the spine in its lumbar section is influenced by: paraspinal muscles and abdominal muscles. In most cases, pain in the lower part of the spine results from overload caused by a sedentary lifestyle. In physiotherapeutic practice the decrease of suffering due to pain in the lumbar section is carried out by means of exercises strengthening selected groups of muscles. A therapeutic programme usually consists of two main parts aiming to strengthen deep abdominal muscles and to increase the strength of dorsal muscles. In order to effectively run physiotherapeutic workout, it is necessary to determine the impact of exercises strengthening certain muscle groups on the load values in the lumbar spine section. Nowadays, mathematical modelling and optimization methods constitute the only non-invasive methods which enable the determination of the values of loads in the skeletal system and evaluation of the force value generated by the muscles during a certain movement (Nowakowska, 2017).

This work aimed to define a change of the values of the loads exerted on the musculoskeletal system in the area of the lumbar spine due to strengthening of the erector spinae muscle.

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## 2. Methods

In order to determine loads exerted on the human body, the Anybody Modeling System environment was used. This software programme provided a modified model of the whole body ('Standing Model'), in which feet have a constant contact with the ground. The model consisted of 69 bones, which were modelled as rigid bodies connected by means of various kinematic pairs as well as over 1000 muscle actons. Forces generated by particular muscles were modelled by means of a Hill-type dependency. Over 180 actons of dorsal muscles and abdominal muscles as well as the impact of intra-abdominal pressure were taken into consideration in the model of the lumbar spine section (Zee, 2007). The values of muscular forces were determined on the basis of a static optimization procedure. A set of equations of balance of individual parts of the model creates boundaries of an optimization task and the objective function describes controlling of the work of muscles by the nervous system. The so-called energy criterion consisting in the energy expenditure minimization was applied in the performed calculations. According to this criterion, the objective function was adopted in a form of a sum of the cubes of muscle forces. The static optimization procedure requires the input of kinematic data into the model. The first stage of the work encompassed experimental tests of motion kinematics of sitting down on a chair and standing up using an optic system called APAS. The determined angles in the joints were entered into the model enabling thus the performance of simulations of loads of the musculoskeletal system. The simulations were carried out for a model of a 50-centile woman of a weight of 65 kg and a body height of 1.65 m. The applied model was calibrated according to the ScalingLengthMassFat procedure. At the beginning of this procedure the body height and weight are entered into the system enabling thus the calculation of the Body Mass Index (BMI). This index is next used to evaluate fat tissue. Lengths of particular elements of body segments are evenly calibrated according to the defined body height of a given person, whereas the percentage of fat tissue is used for the assessment of muscular forces. The applied model of the whole body was subjected to verification consisting in the comparison of the results obtained on the basis of simulations of the activation of the erector spinae muscle with the EMG signal recorded during experimental tests. Moreover, the values of reactions obtained in intervertebral joint Th12-L1 coincide with the results of in vivo measurements conducted by Rohlman et al. (2014). The application of the methods of mathematical modelling and static optimization (enabling the solution of the reverse dynamic task) made it possible to determine the values of loads of the musculoskeletal system in the lumbar spine section, i.e. the reaction components in individual intervertebral joints and the values of muscular forces. This work encompassed the research on the impact of the strengthening of the erector spinae muscle on the obtained values of loads exerting forces in the area of the lumbar spine. The effect of the strengthening of the muscle was achieved by introducing various values of physiological cross section (PCSA) into the model of muscular forces. The force generated by a muscle depends on the above-mentioned PCSA values. Simulations were performed by means of increasing the PCSA values of the erector spinae muscle by 25 %, 50 %, 75 % and 100 %. The model of the erector spinae muscle consisted of four groups of muscles, which were divided into the total number of 29 bundles – muscle fibres on each side, according to the description by Bagduk et al. (1992). Simulations were performed for two selected positions of the recorded activity, i.e. for the upright standing position and sitting down (just until the moment of touching the surface of the chair). The applied model and analyzed positions have been presented in Figs. 1 and 2.

a) b)

*Fig. 1: Analyzed positions: a) standing position; b) sitting down.*

*Fig. 2: Erector spinae muscle ‘ in the applied model.*

## 3. Results and discussion

The values of resultant reactions in joint L5-Sacrum which were obtained in subsequent simulations of the strengthening of the erector spinae muscle for the upright standing position and sitting down have been presented in Tab. 1. Fig. 3 presents percentage changes of the load values resulting from the increase of the cross section of all muscle fibres of the erector spinae muscle.

*Tab. 1: Values of resultant reaction in joint L5-Sacrum for the strengthening of erector spinae muscle.*

| PCSA values of the erector spinae muscle [%] | Resultant reactions in joint L5-Sacrum [N] | |
|---|---|---|
| | Standing position | Sitting down |
| 100 | 432.77 | 1159.62 |
| 125 | 440.53 | 1192.58 |
| 150 | 447.80 | 1219.39 |
| 175 | 452.69 | 1242.66 |
| 200 | 455.68 | 1259.95 |

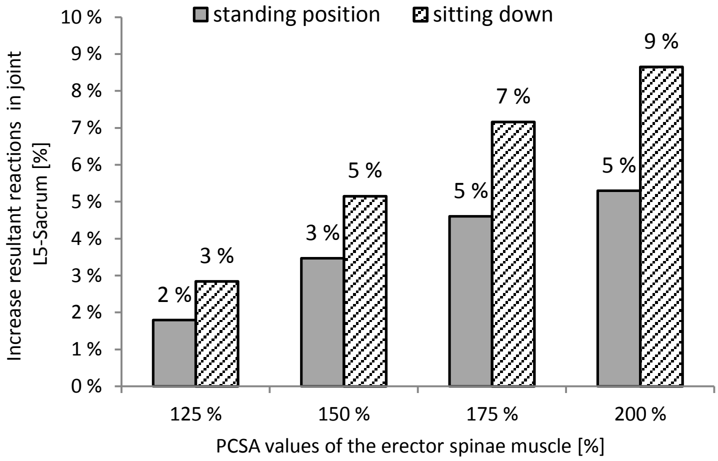


*Fig. 3: A change of reaction value in joint L5-Sacrum in upright standing position and during sitting down due to the increase of cross section of erector spinae muscle.*

It was observed that the double increase of the cross section of the erector spinae muscle in a position of a forward bend may cause the increase in the reaction in joint L5-Sacrum by almost 10 %. Considerably lower differences in percentages were noted for the upright standing position due to the fact that the muscles building the erector spinae muscle constitute a set straightening the spinal column. They contribute to maintaining an upright posture of the body. Due to the points of attachment of individual muscle actons, the increase of their PCSA and the force generated by them cause the compression of subsequent vertebrae. The simulation results enabled also the determination of forces generated by the muscles acting in the lumbar spine section. One of the most active muscles during the analyzed movements was the transverse abdominal muscle. It was observed that the strengthening of the erector spinae muscle resulted in the decrease of the force value generated by the transverse abdominal muscle. The double increase of the cross section of the erector spinae muscle causes more than double decrease of the force value generated by the transverse abdominal muscle during a forward bend (Fig. 4). The transverse abdominal muscle is one of the muscles taking part in the creation of the abdominal prelum, that is why the strengthening of the erector spinae muscle also causes a considerable reduction of the intra-abdominal pressure (Fig. 5).

## 4. Conclusion

The performed mathematical simulations along with optimization techniques made it possible to determine the values of loads of the musculoskeletal system in the lumbar spine section (Tab. 1). It was noted that the increase of the PCSA of the erector spinae muscle causes the increase of reactions in the lumbar spine. Moreover, it was observed that the strengthening of the sole erector spinae muscle may cause the reduction of the force value generated by the transverse abdominal muscle and the intra-abdominal pressure. The above-mentioned conclusions partly confirm hypotheses proposed by physiotherapists. They suggest that better effects, namely greater reduction of pain ailments, are achieved by applying exercises which strengthen both dorsal and abdominal muscles or those which strengthen only abdominal muscles. In addition, the results of this work provide to some extent the explanation why stressed people very often complain of backbone pain. The reason for that could be an excessive tension of the dorsal muscles, which results in the increase of loads in spinal bone structures and intensifies pain. As follow-up of this work it is planned to examine the impact of the strengthening of transverse abdominal muscles on the values of loads in the lumbar spine section. The results obtained from the simulations may be useful in a daily physiotherapeutic practice to increase the efficiency of a therapeutic training programme. The analysis of the research results will make it possible to indicate to what extent the strengthening of particular paraspinal muscles will influence the values of loads in the lumbar spine section.

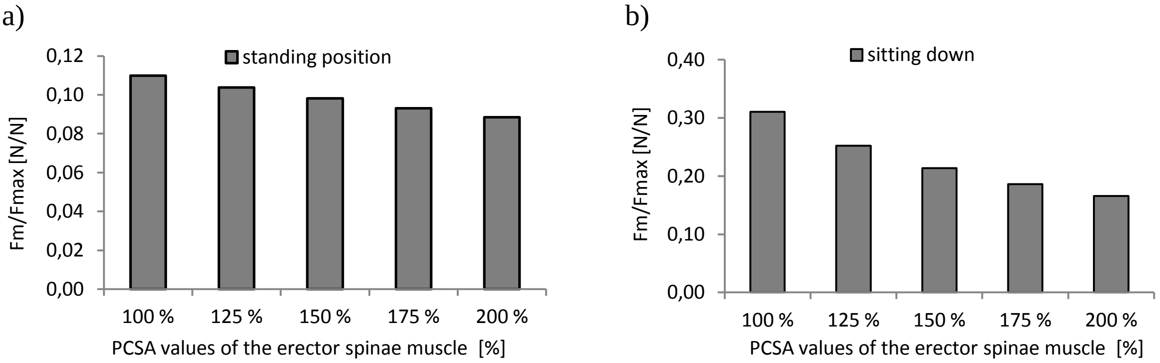


*Fig. 4: Force value of transverse abdominal muscle standardized in relation to maximum force which can be generated by this muscle for subsequent values of cross section of erector spinae muscle during: a) upright standing position, b) sitting down.*

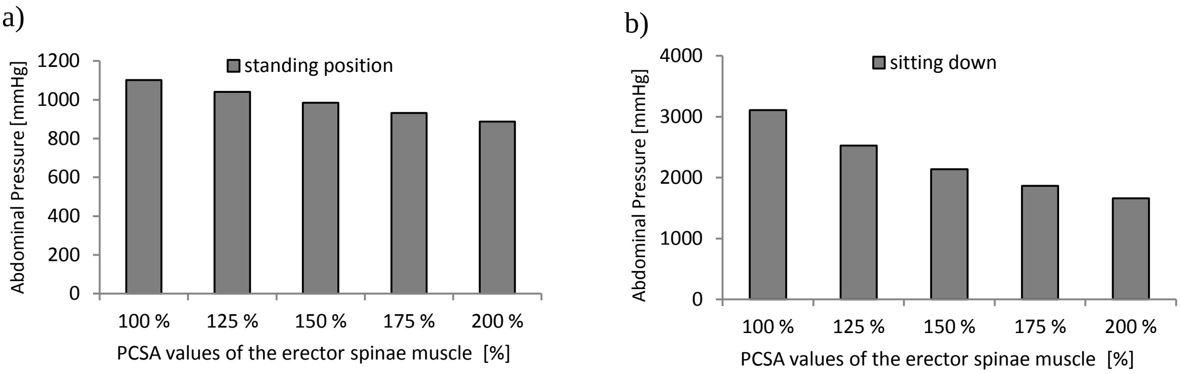


*Fig. 5: Value of intra-abdominal pressure for subsequent values of cross section of erector spinae muscle during: a) upright standing position, b) sitting down.*

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