



Myoelectric Activity of Individual *Lumbar Erector Spinae* Muscles Variation by Differing Seat Pan Depth

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Abstract

Background: The chair influences the position of the user in relation to his or her devices. Prolonged static sitting is a frequently mentioned risk factor for low back pain. Seat design, thus, plays an important role in the study of human sitting. Quantitative information is needed on what happens to body when one sits in chairs with different seat depth.

Objective: To determine the myoelectric activity (EMG) of individual *lumbar erector spinae* muscles after sitting in chairs with different seat pan depth.

Methods: EMG recordings were taken using surface electrodes placed on the *lumbar erector spine* muscles of 25 normal, volunteer subjects. EMG recordings for muscle activity were made while the study participants were in a comfortable position and performed the required tasks. The experiments investigated with 3 seat depths according to the 5th, 50th and 95th percentiles of the buttock popliteal length. The recorded EMG data were normalized to the maximal voluntary contraction. The mean EMG recording was calculated for each of the 3 chairs tested. A mixed model was used to assess the differences among the situations.

Results: A significant ($p < 0.05$) difference was observed between the mean EMG recordings for the 3 tested seat pan depths. EMG activity was higher in seats with the 5th and 95th percentiles compared with that for the seat with 50th percentile of buttock popliteal length depth.

Conclusion: The seat pan depth used during a comfortable position has a significant effect on the level of myoelectric activity in the lumbar erector spinal muscles. The finding of this study may contribute to our understanding of the biomechanics of sitting.

Keywords: Ergonomics; Anthropometry; Fatigue; Muscles; Electromyography

Introduction

With change in social structure and working environment, most people spend an increasing amount of time in seated postures between 50% to 86% of the workday, depending on the occupation.¹⁻³ In office work, 82% of the time is spent on a seated position.⁴ The chair in-

fluences the position of the user in relation to his or her devices, and thus, the musculoskeletal demands placed on the worker.⁵ Riccò, *et al*, recognized a higher prevalence of musculoskeletal diseases (MSDs) among those whose workstations do not meet all the ISO standard (9241-5:1998) requirements,⁶ with a pre-eminent role for the chair.⁷ Prolonged static sitting is a fre-

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quently mentioned risk factor for low back pain (LBP).⁸⁻¹⁰ The negative effect of the seated posture associated with increased paraspinal muscle activity has also been reported.¹¹ Less paraspinal muscle effort necessary to stabilize the spine, may prevent muscle fatigue and improve the overall comfort for the seated individuals.¹² Therefore, reducing paraspinal muscle activity would minimize LBP.

Any posture that produces constant static muscular work induces fatigue. The purpose of taking a sitting posture is, however, to reduce the fatigue.¹³ Seat design plays an important role in the study of human sitting.¹¹ Without a proper design, sitting will require greater muscular force and control to maintain stability and equilibrium. This, in turn, results in greater fatigue and discomfort and is likely to lead to poor postural habits as well as back complaints. When the seat is too deep, the front edge of the seat will press into the area just behind the knees, cutting off circulation to the legs and feet. Seat depth mismatch with thigh length creates strong stresses on the thigh.¹⁴ Therefore, the depth of the seat should be slightly shorter than the length between the back of the knee and thigh. Moreover a large depth of the seat does not allow appropriate use of back support, which causes curvature of the spine (kyphosis) that may lead to dis-

comfort.¹⁵ To alleviate the discomfort, the person in the seat will slide forward and lose proper lumbar and backrest support. Trunk inclination affects myoelectric activity (EMG) levels—the lumbar muscle activity is greater in anterior than posterior sitting, where the feet support more or less than a quarter of the body weight, respectively.¹³ Therefore, the seat pan is a critical variable in seat design; it is the most important feature needing improvement.¹⁶ Recommendations for seat pan depth have been based on empirical reasoning and the so-called common industry practice.¹⁷⁻²⁰ It is natural for dimensions such as seat pan depth to vary among standards and countries. The measures of buttock-popliteal length (BPL) are needed to better understand the impact of chair depth on posture. However, to the best of our knowledge, the BPL dimension was not taken into account in seat design. Furthermore, specific measurements, such as popliteal height, knee height, BPL, and elbow height are necessary to determine the furniture dimensions that enable a correct sitting posture.²¹⁻²²

In spite of the wealth of different measures and the producers' claim of ergonomic quality of their products, surprisingly little is known about the consequences of seat pan depth variation on the biomechanics of spinal muscles in seated posture. The reason is that the human body, as a mechanical system, is equally difficult to investigate experimentally and to model mathematically. Therefore, more quantitative information is needed on what happens to the body when sitting in chairs with different seat depth. To the best of our knowledge, there are few quantitative studies on the relationship between lumbar spine muscles activity and seat design parameters. However, the features of a seat pan that have been researched in the past have been somewhat limited to contouring or cushioning in relation to interface pressures and comfort²⁰ seat pan

TAKE-HOME MESSAGE

- The negative effects of a seated posture is associated with increased paraspinal muscle activity.
- Any postures that produce constant static muscular work induces fatigue.
- Myoelectric activity analysis can provide further insights into the force developed by a muscle.
- The muscles working at high and low co-contraction coefficient indices get fatigued faster than usual.

slope and vertical height of the seat.²⁴⁻²⁶ Anderson and Ortengren²⁷ examined the effect of backrest angle in supported sitting and found that it has the greatest effect on reducing EMG of the *erector spinae*. They concluded that increasing the backward lean of the backrest results in less *erector spinae* activity. However, none have examined how changing the seat pan depth would affect the lumbar spine muscles activity. Additionally, there are no studies to date on biomechanical measures associated with seat pan depth made over an extended period.

EMG analysis can provide further insight into the force developed by a muscle.²⁸ The *erector spinae* muscles function is keeping the spinal position erect. Both the static postural role of *erector spinae* muscles and their dynamics, therefore, have practical significance in studies of the activities of daily activities and the field of ergonomics. The *erector spinae* muscles may be more active when one sits in an unsupported seat compared with the time when taking a standing posture, thus inducing fatigue.¹³

The present study was conducted to explore the EMG activity of individual lumbar erector spinae muscles variation by differing seat pan depth. The co-contraction coefficient index (CCI), which shows simultaneous co-contraction of both muscles, was also quantitatively calculated.

Materials and Methods

Twenty-five healthy male students aged between 20 and 35 years were selected from Tabriz University of Medical Sciences students, using a simple random sampling method. All participants were healthy, engaged in average levels of physical activity, and reported no LBP occurred during at least the year preceding the study; they had not been visited by a physician, physiotherapist, chiropractor, or other

health care professional for LBP; nor had they been absent from work because of LBP. The participants were also excluded from the study if they had a body mass index >30 kg/m². All participants who met the criteria set were invited to participate in the study. The test procedure was explained in more details; a demonstration was given. Written informed consent was obtained from each participant prior to the study.

Three chairs with different seat pan depths were made. To suit the majority of the users, the size was chosen between the 5th percentile of female and 95th percentile of male measures.²⁹ The experimental chairs seat pans were therefore made according to 5th, 50th, and 95th percentiles of BPL of the data provided by Sadeghi, *et al.*³⁰ The values for Iranian population aged 20–65 years were 407 mm (seat A), 459 mm (seat B), and 515 mm (seat C), respectively. Other features (color, model, height, material, handles, *etc*) of the prepared chairs were similar. The chairs had an armrest height of 245 mm, backrest height of 470 mm, backrest width of 385 mm, backseat inclination of 120°, and seat pan width of 430 mm.

The experiment was conducted from April to July 2015. Data collection was completed in a session of about 3.5 h in the same laboratory for all tests. All procedures were carried out in between 9:00 and 12:30 in a quiet laboratory with indoor temperature kept at 22 °C and appropriate light intensity. The same investigator performed all the procedures to ensure uniformity. Each subject was randomly tested on all of the experimental seats to avoid any order effects. There were six possible sequences for testing subjects on the three seats. In each test a standardized one-hour task was performed. During the one hour, the participant was not allowed to rise from the chair. Then, the height of the seat was adjusted to slightly below knee height,

For more information on trapezius muscle activity among dentists using ordinary dentistry chairs see <http://www.theijoem.com/ijoem/index.php/ijoem/article/view/138>



resulting in a knee angle of slightly $>90^\circ$ when the feet were in full contact with the floor. This height was measured and reproduced in each of the experimental test. The height of the desk surface was aligned with the surface of the arm supports. The participants were then asked to adopt a comfortable position on the seat and take up the required tasks including writing a text, watching a movie on a projection screen, and copying a text from the blackboard in front of the lab. These tasks were considered to be typical for real school activities and the adopted postures. To reduce the accumulated effect on the muscles, measurements were only made after participants had a break. Participants were also allowed to have a 15-min rest in the recumbent posture between consecutive trials.³¹ EMG was recorded at time 0, 15, 30, 45, and 60 min for 60 seconds.

EMG was recorded using ME6000 Bio-monitor EMG System (revision MT-M6T16-0), which has 16 channels with bipolar surface electrodes made of Ag/AgCl (silver and silver chloride, 55 mm). Careful skin preparation, which involved abrading the skin and cleaning it with alcohol, to ensure that impedance between the reference electrode and each of the recording electrodes was $<5\text{ k}\Omega$ and that the signal-to-noise was high. For recording the electrical activity of each muscle, the surface disposable electrodes were fixed to the targeted muscles using Basmajian method³² before connecting to the EMG device. The electrodes were placed bilaterally 3 cm on the left (L) and right (R) sides of the *spinous processes* at L3 (L&R) and L4 (L&R) levels on the erector spine along the fiber orientation.³³ A reference electrode was connected 20–30 mm away from the bipolar electrodes over the *spinous process* of the lumbar vertebrae. For finding the surface location of the third lumbar vertebrae, either the navel or the highest point of the iliac crest was used in such a way that both

the navel and the highest point of the iliac crest are placed on the surface of the third and fourth lumbar vertebrae. Surface electrodes were secured onto the shaved and cleaned skin above muscles. Adhesive plaster used for controlling the electrodes placement during test.

For removing the noises created by the computer (for lack of a standard earth connection) the computer case was connected to the earth using a cable and while recording EMG, unnecessary power sources, mobile phones and any electric devices in the vicinity of the recording device (which could potentially create noises) were switched off.

The data were analyzed using MegaWin software ver 3.01 with 200-ms delay. The EMG signals were band passed filtered at 20–500 Hz to eliminate undesired artifacts, such as sudden movement. The EMG signals were sampled at a rate of 1000 Hz. The EMG raw data were averaged by using root mean square (RMS) to obtain the average amplitude of the EMG signal. RMS of the EMG was obtained using a time window of 5-ms sliding average.

Maximum Voluntary Contraction (MVC) Protocol

Before data collection, all participants performed at least three MVC in the Biering-Sorenson position to obtain an estimate of their maximum erector spine muscle activation. For obtaining the MVC, the participant was positioned prone with their legs and pelvis securely strapped to the platform and leaving the trunk unsupported and their shoulders pressed using the palms for five seconds.³⁴ In the meantime, the individual was asked to show the maximum resistance against the force, trying to bend their back. The Biering-Sorenson position was chosen for normalization. For muscle relaxation and recovering energy sources (ATP-PC) in each muscle, a two-minute rest break was given between the

successive MVC measurements.³⁵

Normal signal (NRMS) of each muscle in each time span was calculated using the following equation:

$$NRMS_i = \frac{RMS_{\max(i)} - RMS_{\min(i \text{ or } MVC)}}{RMS_{\max(MVC)} - RMS_{\min(i \text{ or } MVC)}} \quad (i=1,2,\dots,5) \text{ Eq 1}$$

The denominator of the fraction in the equation was calculated by subtracting the maximum RMS in the three phases of MVC from the minimum of RMS of each phase of the three phases of MVC.

To compute the co-contraction coefficient index (CCI), NRMS low(i) and NRMS high(i) were selected among NRMS of the two muscle groups (R&L erector spine muscles) in each test. At each time, one of these muscles had a relative minimum value (NRMS low) while the other had a relative maximum value (NRMS high). This process was repeated for nine steps (i=1–9; Equation 2). So, nine CCIs were obtained for 15-min intervals for each muscle pair in each position. The mean was then computed based on the nine CCIs calculated during two hours sitting as a means for comparing CCI variations in both positions.

$$CCI = \sum_{i=1}^9 \frac{NRMS_{Low}(i)}{NRMS_{High}(i)} (NRMS_{Low}(i) + NRMS_{High}(i)) \text{ Eq 2}$$

Statistical Analysis

SPSS® ver 16.0 (SPSS Inc, IL, USA) was used for data analysis. One-sample Kolmogorov-Smirnov test was used to assess normality of variable distributions. NRMS and CCI of each activity were considered the dependent variable; seat depth, time, and electrical activity of the L&R erector spine muscles were considered independent variables. In each of the factors examined a mixed model with the REML estimating method and AR(1) covariance structure was used. A p value <0.05 was considered statistically significant.

Results

The current study data are obtained from 25 healthy male subjects with no previous or ongoing back problems. Their mean age was 25.0 (SD 2.7) years; weight, 67.1 (7.3) kg; height, 1.76 (6.0) m; and BMI, 23.3 (3.0) kg/m².

The mean NRMS was 6.28% (95% CI 5.88% to 6.68%) for the left hand and 6.01% (95% CI 5.61% to 6.41%) for the right hand (p=0.351, Fig 1). Each EMG value represents myoelectric muscle activity during sitting in three studied chairs with different seat depth relative to their MVC activities. The amount of the electrical activity of lumbar erector spine muscles in seat B was significantly (p<0.001) lesser than that recorded for seats A and C; that of seat A was also significantly (p<0.001) lesser than that of seat C. The myoelectric activity recorded was not significantly changed over the study period in each seat (p=0.89) (Fig 1).

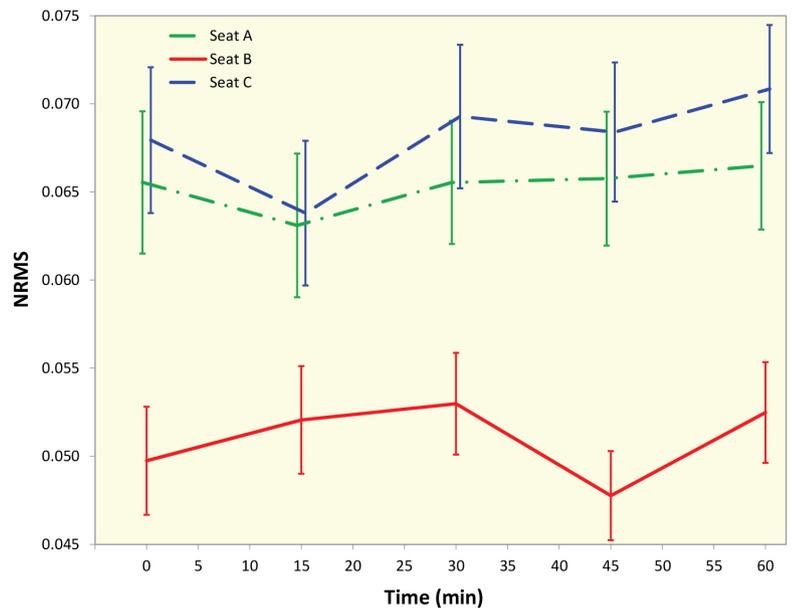


Figure 1: Mean NRMS measured over the study period for seats with different pan depths examined. Error bars represent the 95% CI for the mean.

Discussion

We found that differences between the myoelectric activities of individual lumbar erector spinal muscles by varying the depth of the seat pan. Muscular activity in seat with a pan depth of 50th percentile of BPL was significantly lesser than that measured in seats with 95th and 5th percentile of BPL. CCI of lumbar erector spine muscles was lowest in seat C and highest in seat A. Consistent with the results of several studies, the muscles working at high and low CCIs get fatigued faster than usual. This finding supported our EMG findings indicating that seat B was much better than seats A and C.

Compared with seat B, the seat pan of seat A was not able to provide full support for the upper legs; more energy was required to maintain a sitting posture, thus, the muscle activity in seat A was 28% higher than seat B. This explains why seat A (5th percentile of BPL) caused a significantly higher muscle activity compared with seat B. The pan depth of seat C was too high; the participant could only sit on the front part of the seat pan, necessitating full support by upper legs. This type of seat pan depth caused the person neglect using the backrest properly. Since there was no contact between the back and backrest, the participant required keeping his lumbar curvature by his own muscle activation instead of backrest support. This would cause kyphosis in the spine and might lead to discomfort. This finding explains why seat C (95th percentile of BPL) caused a significantly higher EMG activity (by 33.4% on average) than seat B. The observed increased myoelectric activities in erector spine muscle during sitting on seats with inappropriate seat pan depths was in agreement with the results of Huang, *et al*, where they found that lumbar disc pressure maintained by lumbar lordosis is higher than that maintained by lumbar

support.³⁶

For continuous and relatively high activity of a fraction of the motor units in muscle can cause muscle ache in other muscle groups.^{37,38} Taking a sitting posture is associated with increased paraspinal muscle activity.^{39,40} Decreasing paraspinal muscle activity may help relief of LBP, as less paraspinal muscle effort is needed to stabilize the spine; this may prevent muscle fatigue and improve the overall comfort for seated individuals.¹² According to the result of the current study, using a seat pan of the 50th percentile BPL produces less erector spine muscle activity. The 50th percentile BPL value for the examined male subjects was 459 mm. Consequently, the depth of the seat pan should not exceed 459 mm. Nevertheless, it should be slightly less than the length between the back of the knee and thigh.

Seat pan depth, as one of the seat dimensions, must be taken into account in designing and selecting chairs. In other words, the population BPL should be considered in selecting chairs.^{24,41} This would lead to having a well-suited seat and maintaining a normal posture that is one of the most important factors for preventing fatigue and musculoskeletal problems and disorders.^{41,42}

This study has some limitations. The study was conducted on a small sample selected from a university population. The results may therefore not be completely generalizable to occupational populations who are habitually exposed to longer durations of office work. In addition, the study period in the current study was short. So it still remains unknown what would have happened after a prolong sitting on chairs. The present study focused on only one aspect of the chair design. Future investigations should also take into account the influence of the seated posture and chair parameters on the development of forces in soft tissue.

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Conflicts of Interest: None declared.

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