Journal of Knowledge Information Technology and Systems

ISSN 1975-7700

http://www.kkits.or.kr

# Analysis of Changes in the Muscle Activity and Fatigue of the Erector Spinae using IT Convergent Type Medical Equipment

**Jung-Hyun Choi***

*Department of Physical therapy, Namseoul University, Korea*

## ABSTRACT

The purpose of this study was to observe how changes in the upper body angle in a sitting posture on a chair affect the muscle activity and fatigue of the erector spinae to provide basic data on a correct sitting posture. This study involved 24 healthy males and females in their 20s. The average body angle of the subjects in each posture was 94 degrees in posture 1, 79 degrees in posture 2, and 109 degrees in posture 3. To examine the signal amount of the erector spinae, the erector spinae in the left and right cervical spine, thoracic spine, and lumber spine was selected, and each muscle's maximal voluntary isometric contraction (MVIC) was measured before the experiment. In the experiment using IT convergent type medical equipment, the three angles measured with a motion analyzer in a sitting posture on a chair were directed, and the electromyography signals for each posture were measured and recorded. Each electromyography signal was compared and analyzed, thereby extracting information on the characteristics of the electromyography signals according to each posture. The muscle activity of the longissimus thoracis increased in postures 1 and 2 compared with that in posture 3, and the muscle activity of the longissimus lumborum increased in posture 3 compared with that in postures 1 and 2($p<0.05$). The muscle fatigue of the left longissimus thoracis (LLT) in posture 1 and the right longissimus thoracis (RLT) in posture 3 was significantly high($p<0.05$). Therefore, as shown in the present experiment, to take a sitting posture while maintaining the upper body angle like in the posture 1 and the posture 2 is considered to be helpful for preventing low back pain or other spinal column diseases.

**KEYWORDS:** Sitting Posture, EMG, Muscle Activity, Muscle Fatigue

**ARTICLE INFO:** Received 21 October 2015, Revised 11 December 2015, Accepted 11 December 2015.

---

*Corresponding author is with the Department of Physical theray, Namseoul University, 91 Daehak-ro Seonghwan-eup, Seobuk-gu, Cheonan-si, 31020, KOREA.
*E-mail address*: rightmind@nsu.ac.kr

## 1. Introduction

Electromyography expresses neuromuscular activity according to muscle contraction into electrical signals and refers to electric current generated according to the flow of ions at both ends of the sarcolemma, and these signals are transmitted through the tissues and reach the electrode surface. The electrical signals delivered by the activity of a motor unit of muscle fibers in adjacent areas that are sensed by electrodes are called the motor unit action potential (MUAP), and this is the basic unit of electromyography signals [1]. By analyzing electromyography data, musculoskeletal stress associated with various postures and activities can be detected [2]. In addition, the relationship between muscle movement and time aspects, power generation and electromyography, and muscle fatigue and electromyography can be compared [2]. Over 100 years have passed since electromyography was developed to measure muscle fatigue. In general, the mean power frequency or median power frequency of an electromyogram is measured during static contraction [3]. In addition, surface electromyography may clarify the activation timing of the muscles, relationship between force and electromyography, and the degree of muscle fatigue [4].

The pressure on support structures that support and protect the body depends on how to take a posture and leads to different effects on the body. When a poor posture is sustained for a long time, it adversely affects different structures and organs, triggering health problems [5]. Spinaldiseasescanoccurwhenthecurveofthespineisincorrectandthedistributionofgravityisunequal . To prevent spinal diseases and improve spinal health, life habits related to postures should be managed, so as to maintain a proper posture [6].

Lumbar diseases can occur due to excessive exercise, accidents, spinal diseases, and aging. Office workers and students, as well as those who drive a car for long periods, commonly complain of lumbar pain. The pain occurs because of the weakening of the lumbar muscles, resulting from a sedentary lifestyle and a lack of exercise. Among those with sedentary lifestyles, proper posture and periodical light exercise may prevent low back pain [7].

According to recent domestic research results, the rate of adolescents with spinal diseases increased from 2.3%of the total patient population in 1987 to 17.8% in 2004, with 9.7% of complaining of spinal pain. The prevalence of spinal disease during childhood is high , and the prevalence gradually increases with aging. Spinal diseases during childhood and adolescence are a predictor of spinal diseases during adulthood [8]. School-related activities, such as sitting for long periods, are risk factors for spinal disease. [8,9]

There have been many studies of the effects of a sitting posture on the human body [8-11]. However, research is lacking on the effects of a prone position or postures that involve bending the head back. Such postures are often seen among school students and office workers. The purpose of this study was to observe how changes in upper body angles in a sitting posture on a chair affect the muscle activity and fatigue of the erector spinae and to provide basic data on a correct sitting posture.

## 2. Methods

### 2.1 Participants

This study involved 24 males and females in their 20s who went to N University located in Chungcheongnam-do. The subjects had no characteristic lesions or a history at the time of the test and had no restriction of movement resulting from pain in standing, flexion, and extension. In addition, they had not experienced lumbar pain in the last 2 years. The general characteristics of the subjects are shown in <Table 1>.

표 1. 대상자들의 일반적 특징
Table 1. General Characteristics of the Subjects

| Characteristics | Means±SD | Range |
|---|---|---|
| Age (years old) | 22.89±1.91 | 21~25 |
| Height (cm) | 167.58±9.36 | 158~177 |
| Weight (kg) | 59.95±10.47 | 49.5~70.4 |

### 2.2 Study procedures

To improve the objectivity and preciseness of each posture , the angles of the subjects' postures were measured with a motion analyzer (SMART-E, BTS, Italy), and the averaged to utilize them for the experiment. When measuring the angles, the end lines of the elbows and hips, in other words, the uppermost area where the hips contacted the chair, were marked on the chair with a tape. The end lines of all the subjects were the same, and their postures were measured. The average angle of the subjects by each posture was 94 degrees in posture 1, 79 degrees in posture 2, and 109 degrees in posture 3. The signals emitted by the erector spinae were measured using a wireless surface electrode electromyography system (Free EMG, BTS, Italy). The diameter of each electrode was 10mm, and the inter-electrode distance was fixed to 20 mm, and the inter-electrode distance was fixed to 20 mm. A 16-bit A/D (analog-tp-digital) card was used to convert all EMG signals. Raw EMG signals were amplified using a single differential amplifier with a common mode rejection ratio of 100 dB, gain set at 500, and noise < 1 μV. signals were sampled at 1500Hz. The distance between the attachment location and anatomical sign point was measured to provide a ground for selection of the same location for all subjects. To reduce noise associated with the electromyography measurement tool and the electrode cable during the experiment, the electrode cable was attached securely with tape to ensure it did not fall on the subject. For normalization work aimed at comparing electromyography among the subjects, each subject's maximal voluntary isometric contraction (MVIC) by each subject and data on each muscle when exerting maximal force against isometric resistance was collected for 3 sec [12]. The MVIC of the erector spinae muscles in the left and right cervical spine, thoracic spine, and lumber spine was measured before the experiment.

표 2. 근육별 전극 부착 위치

Table 2. The Locations of the Electrodes Attached to Each Muscle

| Muscle | Sites of Electrode Attachment |
|---|---|
| Longssimus cervicis | 2 cm lateral to the spinous process of the fourth cervical spine |
| Longssimus thoracis | 5 cm lateral to the spinous process of the ninth thoracic spine |
| Longssimus lumbrorum | 2 cm lateral to the spinous process of the second lumbar spine |

In the experiment, three angles were measured with a motion analyzer in a sitting posture on a chair, and the electromyography signals emitted during each posture were measured and recorded. Each electromyography signal was compared and analyzed, thereby extracting information on characteristics of electromyography signals according to each posture. Based on this, postures triggering excessive tension to the muscles for a long time were detected by differentiating proper postures and improper postures and detecting the state of fatigue of the muscles around the spine.

After the subject adopted a static posture, the muscle load of the erector spinae was measured using electromyography while maintaining each posture for 1 min, and muscle fatigue was measured for 5 min by adding 4 min. During changes of posture, a 5-min interval was given to reduce the fatigue effect and the muscle tone applied to the erector spinae was reduced by lying on a mat this rest period. In addition, for the single blind test measurement was taken by one subject in the laboratory [13].

### 2.3 Data Processing and Analysis

The SPSS version 18.0 program was used for the data analysis in this study. The normal distribution of the data was verified using the Kolmogorov-Smirnov test. To compare the muscle activity of the erector spinae according to the changes in sitting postures, a one-way analysis of variance was used. For the comparison among the postures, Scheffe’s test was performed. The level of statistical significance was set at $\alpha$=005.

## 3. Results

### 3.1 The muscle activity according to the postural changes and multiple comparisons

According to the comparison of the muscle activity of the erector spinae in the different postures, there was a significant difference in the activity of the right longissimus thoracis (RLT) ($p<0.05$).

According to the results of a post hoc test of the muscle activity of the RLT in accordance with postural changes, the muscle activity in posture 1 was significantly higher than that in posture 3, and the muscle activity in posture 2 was significantly higher than that in posture 3 ($p<0.05$).

표 3. 자세 변화에 따른 척추기립근의 근활성도 분석

Table 3 . Analysis of the Muscle activity of the Erector Spinae According to Postural Changes

| | | N | Average | Standard deviation | F | p |
|---|---|---|---|---|---|---|
| LLC | Posture 1 | 24 | 9.8486 | 5.2238 | .83 | .920 |
| | Posture 2 | 24 | 9.7768 | 5.2785 | | |
| | Posture 3 | 24 | 10.5185 | 9.4513 | | |
| | Sum | 72 | 10.0480 | 6.8495 | | |
| LLT | Posture 1 | 24 | 18.3067 | 14.1104 | 2.390 | .099 |
| | Posture 2 | 24 | 17.3201 | 12.4470 | | |
| | Posture 3 | 24 | 11.3928 | 8.2005 | | |
| | Sum | 72 | 15.6732 | 12.0799 | | |
| LLL | Posture 1 | 24 | 8.6945 | 5.8476 | .478 | .622 |
| | Posture 2 | 24 | 7.6359 | 4.8476 | | |
| | Posture 3 | 24 | 9.3668 | 7.5491 | | |
| | Sum | 72 | 8.5657 | 6.1372 | | |
| RLC | Posture 1 | 24 | 13.5361 | 32.7019 | .394 | .676 |
| | Posture 2 | 24 | 8.1322 | 5.4634 | | |
| | Posture 3 | 24 | 11.5436 | 16.2939 | | |
| | Sum | 72 | 11.0707 | 21.1460 | | |
| RLT | Posture 1 | 24 | 14.2409 | 6.8750 | 5.979 | .004* |
| | Posture 2 | 24 | 15.3340 | 7.7708 | | |
| | Posture 3 | 24 | 9.0407 | 5.3401 | | |
| | Sum | 72 | 12.8719 | 7.1941 | | |
| RLL | Posture 1 | 24 | 11.6799 | 20.2663 | .582 | .561 |
| | Posture 2 | 24 | 8.8936 | 7.8804 | | |
| | Posture 3 | 24 | 7.5667 | 8.5076 | | |
| | Sum | 72 | 9.3801 | 13.4013 | | |

p* <0.05, LLC: Left longissimus cervicis, LLT: Left longissimus thoracis, LLL: Left longissimus lumborum, RLC: Right longissimus cervicis, RLT: Right longissimus thoracis, RLL: Right longissimus lumborum

### 3.2 Muscle Fatigue according to the Postural Changes and Multiple Comparisons

The comparison of the muscle fatigue of the erector spinae in accordance with postural changes revealed a significant difference in that of the RLT and left longissimus thoracis (LLT) ($p<0.05$).

According to the results of a post hoc test of RLT and LLT muscle fatigue in accordance with the postural changes, the muscle fatigue of both the RLT and LLT was significantly higher in posture 1 than in posture 3 ($p<0.05$).

## 4. Discussions and Conclusions

Adopting a sitting, standing, or bending posture for long periods while undertaking repetitive work places an abnormal load on the spinal joints and restricts the range of motion, potentially triggering spinal diseases [14,15]. When sitting for a long time, not maintaining the natural curve of the spine, flexing the upper body forward, extending the body excessively, maintaining a lopsided left or right posture, the muscles around the spine require more effort and energy [16]. The erector spinae may continuously maintain a proper sedentary posture through balanced action, maintenance of balanced muscle strength, and endurance of the erector spinae is very important [16]. The present study observed how the muscle activity and fatigue of the erector spinae, which plays an important role in a sitting posture, changed according to the angle of the upper body in a sitting posture. The aim of the study was to provide basic data on a correct sitting posture. In the present study, the muscle activity of the RLT in posture 1 and posture 2 was significantly higher than that in posture 3. The muscle activity of the LLT in postures 1 and 2 increased more than that in posture 3, although this increase was not significant. In addition, the muscle activity of the left longissimus lumborum was higher in posture 3 than in postures 1 and 2, although the increase was not statistically significant.

표 4. 자세 변화에 따른 근활성도의 다중비교

Table 4. Multiple Comparison of the Muscle Activity According to Postural Changes

| Dependent variable | (I) Posture | (J) Posture | Average difference (I-J) | Standard error | Significance probability | 95% Confidence interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower limit | Upper limit |
| RLT | Posture 1 | Posture 2 | -.23060 | 2.52793 | .996 | -6.7780 | 6.3168 |
| | | Posture 3 | 6.60629 | 2.52793 | .048* | .0589 | 13.1537 |
| | Posture 2 | Posture 1 | .23060 | 2.52793 | .996 | -6.3168 | 6.7780 |
| | | Posture 3 | 6.83689 | 2.52793 | .039* | .2895 | 13.3843 |
| | Posture 3 | Posture 1 | -6.60629 | 2.52793 | .048 | -13.1537 | -.0589 |
| | | Posture 2 | -6.83689 | 2.52793 | .039* | -13.3843 | -.2895 |

$p^* < 0.05$, RLT: Right longissimus thoracis

For such reason, posture 3 compared to posture 1 is a posture where the lumbar spine becomes kyphotic. It is an anatomical posture where the proper length of the erector spinae cannot be maintained properly to maintain a posture [16]. In a study by Hong as well, muscle fatigue in between a sitting posture with the upper body standing straight and a sitting posture with the upper body tilting sideways was compared. The greater the angle of tilting sideways, significantly higher muscle fatigue [18]. In the present study as well, a similar result to that of of the previous research was observed because when continuous load is given to some muscle around the spinal column by the angle of the upper body, the length of the muscle as well as muscle strength are affected. Such repetitive stress may become one of the most common causes of low back pain or other spinal diseases [17,19].

In the sitting posture adopted in posture 3 in this study, the activity and fatigue of the erector spinae was decreased compared to that in postures 1 and 2. However, to maintain the posture, excessive use of surrounding anatomical structures was triggered. Excessively used structures are repetitively damaged, and as time goes by, the cross-sectional area of the muscle around the spine is decreased, resulting in muscle atrophy, which exacerbates low back pain [12,20].

A limitation of this study is that the subjects included only healthy undergraduates in their 20s. In addition, the number of subjects was small at 24 and it is difficult to generalize this study result. Future research needs to compare healthy people and obese people and examine the effects of postural changes on patients with low back pain. In addition, this study failed to measure the muscle activity of the deep muscles according to the postural changes and measured only the muscle activity of the superficial muscles using surface electrodes. Therefore, future research needs to investigate postural changes affect the activity of the deep muscles.

## References

[1] R.-M. Enoka, and J. Duchateau, *Muscle fatigue: what, why and how it influences muscle function,* The Journal of Physiology, Vol. 586, No. 1. pp. 11-23, 2007.

[2] F. Felici, *Neuromuscular responses to exercise investigated through surface EMG,* Journal of Electromyography and Kinesiology, Vol. 16, No. 6. pp. 578-585, 2006.

[3] C.-J. De Luca, *Myoelectrical manifestations of localized muscular fatigue in humans*, Critical reviews in biomedical engineering, Vol. 11, No. 4. pp. 251-279, 1984.

[4] C. Nordander, G.-A. Hansson, L. Rylander, P. Asterland, J.-U. Byström, K. Ohlsson, I. Balogh, and S. Skerfving, *Muscular rest and gap frequency as EMG measures of physical exposure: the impact of work tasks and individual related factors*, Ergonomics, Vol. 43, No. 11. pp. 1904-1919, 2000.

[5] D. Zivkov, N. Saponja, and C. Dunderski, *Poor body posture from the aspect of kinesiolog*, Medicinski pregled, Vol. 43 No. (9-10). pp. 423-425, 1990.

[6] F. Zairi, P. Marinho, M. Allaoui, and R. Assaker. *New advances in the management of thoracolumbar spine metastasis*. Bulletin du Cancer, Vol. 100, No. 5. pp. 435-441, 2013.

[7] P.-P. Kuijer, J.-H.Verbeek, B. Visser, L.-A. Elders, N. Van Roden, M.-E. Van den Wittenboer, M. Lebbink, A. Burdorf, and C.-T. Hulshof, *An evidence-based multidisciplinary practice guideline to reduce the workload due to lifting for preventing work-Related low back pain*, Annals of Occupational and Environmental Medicine, Vol. 26, No. 26. p. 16, 2014.

[8] S. Kim, and J.-S. Kim, *Knowledge of good posture and postural habits in elementary school children*, Child Health Nursing Research, Vol. 13, No. 2. pp. 182-190, 2007.

[9] S.-H. Lee, *A study on the association between sitting posture and back pain*, Unpublished doctoral dissertation, Inha

University, 2006.

[10] M.-S. Choi, I.-J. Jung, and H.-W. Jeon, *The effect of sitting postures on spinal pelvic curvature and trunk muscle activation in low back pain*, Journal of the Korean Academy of University Trained Physical Therapis, Vol. 16, No. 2. pp. 31-39, 2009.

[11] K.-O. Sullivan, P.-O. Sullivan, M.-O. Keeffe, L.-O. Sullivan, and W. Dankaerts, *The effect of dynamic sitting on trunk muscle activation: a systematic review*, Applied Ergonomics, Vol. 44, No. 4. pp. 628-635, 2013.

[12] J.-T. Kim, and S.-H. Park, *Effect of scapular stabilization exercise on EMG change of shoulder girdle and trunk muscle during archer`s shooting*, Journal of Sport and Leisure Studies, Vol. 38, No. 2. pp. 1003-1010, 2009.

[13] W.-J. Jung, *Effects of a wallet in the back trouser pocket on paraspinal muscle activity in sitting*, Unpublished doctoral dissertation, Yonsei University, 2009.

[14] G.-B. Andersson, *Epidemiologic aspects on low-back pain in industry*, Spine, Vol. 6, No. 1. pp. 53-60, 1981.

[15] A. Magora, *Investigation of the relation between low back pain and occupation*, Scandinavian journal of rehabilitation medicine, Vol. 7, No. 4. pp. 146-151, 1981.

[16] D.-A. Neumann, *Kinesiology of the musculoskeletal system: Foundations for Physical Rehabilitation(2nd ed)*, St. Louis: Mosby, 2009.

[17] V.-J. Caiozzo, *Plasticity of skeletal muscle phenotype: mechanical consequences*, Muscle and Nerve, Vol. 26, No. 6. pp. 740-768, 2002.

[18] S.-C. Hong, *The evaluation of the sitting posture by EMG spectrum and muscular strength, Unpublished doctoral dissertation*, Myongji University, 2004.

[19] B. Chok, R. Lee, J. Latimer, and S.-B. Tan, *Endurance training of the trunk extensor muscles in people with subacute low back pain*, Physical Therapy, Vol. 79, No. 11. pp. 1032-1042, 1999.

[20] J. Hyman, and C Liebenson, *Spinal stabilization exercise program: Rehabilitation of the spine*, Williams and Wilkins, 1996.

[20] B. Valachi, K. Valachi, *Mechanisms leading to musculoskeletal disorders in dentistry*, The Journal of the American Dental Association. Vol. 134, No. 10. pp. 1344-1350, 2003.

---

## IT 융합형의 의료기기를 사용한 척추기립근의 근활성도와 근피로도 변화 분석

**최정현**
*남서울대학교 물리치료학과*

### 요 약

본 연구의 목적은 의자에 앉은 자세의 상체 각도변화가 척추기립근의 근활성도와 피로도에 어떠한 영향을 미치는지 관찰하여, 올바른 앉은 자세에 대한 기초자료를 제공하는 것이다. 본 연구는 건강한 성인 20대 남녀 24명을 대상으로 실시하였다. 실험 대상자들의 자세별 평균 각도는 자세1 에서 94°, 자세2 에서 79°, 자세3 에서 109° 가 측정 되었다. 척추기립근의 신호량을 알아보기 위하여 좌우의 경추, 흉추, 요추부 척추기립근을 선택하여, 실험에 앞서 각 근육의 MVIC 값을 측정 하였다. 실험을 위해 의자에 앉은 상태에서 동작분석기로 측정한 세 가지의 각도를 연출하고 각각의 자세에 따른 근전도 신호를 IT 융합형 의료기기를 사용하여 측정, 기록한다. 각각의 근전도 신호를 비교, 분석함으로서 자세에 따른 근전도 신호의 특징

정보를 추출한다. 자세1과 자세2에서 흉추기립근의 근활성도가 자세3에서 보다 증가 하였으며, 자세3에서 요추기립근의 근활성도가 자세1과 자세2보다 증가 함을 알 수 있다. 또한, 자세1에서 왼쪽 흉추기립근과 오른쪽 흉추 기립근가 자세3에서 근피로도가 유의하게 높게 나왔다. 따라서 척추 기립근에 비정상적인 부하를 감소시키고자 한다면 등허리 근육과 골반을 의자 등받이에 밀착시켜 앉도록 한다고 사료된다.

## Acknowledgments

This funding for this study was provied by Namseoul University in 2015.

**Jung Hyun Choi** received the bachelor’s degree in the Department of physical theray the from the Namseoul University in 2010. He received the M.S. degree and the Ph.D. degree in the Department of physical therapy from Yongin University in 2003 and 2010, respectively. From 2010 to 2015, he was a researcher at HanKook Knowledge Research Institute. He was a professor in the Department of physical therapy at Namseoul University from 2010 to the present. He has been a professor in the Department of physical therapy at Namseoul University since 2010. His current research interests include electrophysiology, Ergonomics. He is a life member of the KKITS.

*E-mail address*: rightmind@nsu.ac.kr