*ICIC Express Letters*
*Part B: Applications*
Volume **10**, Number **8**, August **2019**

ICIC International ©2019 ISSN 2185-2766
pp. 743–748

# ERGONOMIC ASSESSMENT OF FOUR DIFFERENT MATTRESSES

Hong-In Cheng[1] and Young-Hee Kim[2]

[1]Department of Industrial and Management Engineering
[2]Graduate School of Digital Design
Kyungsung University
309 Suyeong-ro, Nam-gu, Busan 48434, Korea
hicheng@ks.ac.kr; 012hellen@gmail.com

Received January 2019; accepted April 2019

Abstract. *By measuring muscle activity on the mattresses with different materials, new type of mattress can be developed that maximizes the subjective comfort. Many different kinds of mattresses are on the market but ergonomic approach to those mattresses is insufficient. EMG and subjective comfort of 35 participants who were asked turning their bodies on 4 different mattresses (latex, soft multi-hardness polyurethane, hard multi-hardness polyurethane, and memory foam) were collected and investigated. Soft polyurethane mattress and latex mattress activated right external obliquethe least for body turning motion. Latex mattress was evaluated subjectively most comfort. In fixed position, memory foam mattress recorded high satisfaction, yet it failed to satisfy the users turning left due to high muscle activity.*

**Keywords:** Mattress, Muscle activity, Subjective comfort, EMG

1. **Introduction.** A human usually spends about one third of his or her time on sleep. Sleep is necessary in the life because it would help maintain and recover the body function. Many people have problems with sleeping [1]. Irregular sleep might deteriorate diabetes and cause high blood pressure and serious mental problems [2-6].

The average work time is increasing and sleep time is decreasing in the modern society. Expanding number of occupations requiring night shifts or three shifts is also responsible for irregular sleep time [7,8]. Wickwire et al. reported approximately 80% of employees work from 8-9 am to 5-6 pm [8].

Internal factors such as high stress level and mental instability disrupt sleep. On the other hand, noise, light, temperature, quality of bed and other interior subjects are the main factors for the satisfaction of sleep [9]. Among all, mattress would be the most important factors that contribute to the quality of sleep.

Muscle activity measured by Electromyography (EMG) and body pressure is mainly employed to evaluate mattresses. Mattress with low mean body pressure is considered to be in high quality. Latex mattress usually generates lower mean body pressure than polyurethane mattress. Moreover, the mattress with softer material is most likely to satisfy the users [10]. Kim and Cheng reported memory foam mattress would offer low body pressure and high comfort [11].

In this study, ergonomic assessment was conducted to compare four types of mattresses: the mattress that consists of latex extracted from rubber tree or crude oil, soft multi-hardness mattresses composed with polyurethane and various chemicals, hard multi-hardness polyurethane mattress and the memory foam mattress. Latex mattress is made from the sap of the rubber tree and its most distinct feature is the elasticity. Memory foam mattress is soft and adaptable because it is made from viscoelastic foam. Multi-hardness

DOI: 10.24507/icicelb.10.08.743

mattresses are designed with 7 zones. Each zone supports different parts of body with different hardness.

Multi-hardness mattress is a new sort of mattress composed with different zones made with different materials or hardness. It is valuable to compare existing mattresses (latex and memory foam mattress) with newly developed mattresses (soft and hard multi-hardness mattress).

2. **Method.** Thirty-five students (20 men and 15 women) in Kyungsung University with no sleeping disorder volunteered to participate in the experiment after reading announcement posted at social media. Each student spent approximately an hour and half on the experiment and received 50,000 KRW (approx. 50 USD).

The characteristics of the participants are given in Table 1. Participants were given the survey asking their sleeping duration; 40.0% of participants reported that they slept for 6∼7 hours while only 14.29% of participants claimed they slept more than 8 hours. Proportion of participants sleeping less than 6 hours and that of the ones sleeping for 7∼8 hours were both 22.86%. In addition, 68.57% responded that they lay on their side while in sleep. 28.57% of the participants reported they faced up while sleeping and 2.86% of the participants answered lying their face down to sleep.

Table 1. Characteristics of the participants (N = 35)

| Gender | N | Age (year) | Height (cm) | Weight (kg) |
|---|---|---|---|---|
| Man | 20 | $23.65 \pm 1.93$ | $175.85 \pm 5.83$ | $73.90 \pm 11.09$ |
| Woman | 15 | $23.53 \pm 2.33$ | $162.37 \pm 7.76$ | $53.67 \pm 9.80$ |

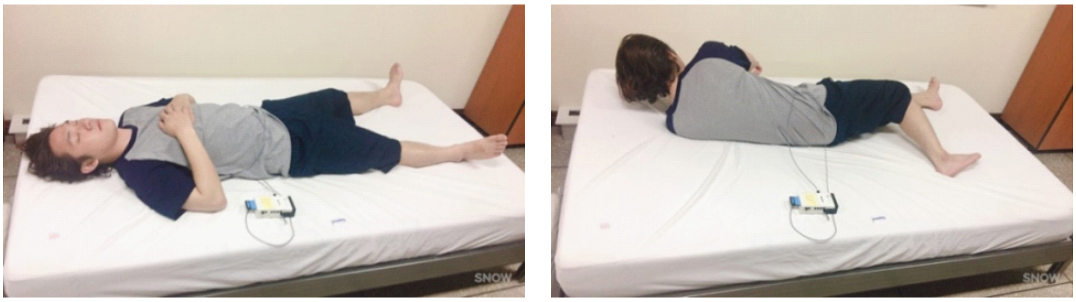
Prior to the experiment, each participant received the document stating the objective and instructions for the research. After being informed the details about the experiment, they were asked to sign the consent form. Participants were then given cotton shirts and short pants to change. When they were ready, we measured their height and weight.

For better understanding about the experiment, participants randomly chose one of four mattresses and lay on it as the instruction told. When everyone finished practice, we began the experiment.

Activity of external oblique required for turning motion on the mattress was measured with Noraxon's TELEmyo 2400T G2. Four Ag/AgCl surface electrodes were attached on the body; two electrodes were attached at left and other two at right external oblique. Left and right external oblique are agonists for right and left trunk rotation respectively. For each part of the muscle, electrodes were separated 2cm apart from each other. To achieve better results, attachment site of electrode was cleaned with alcohol.

MVIC (Maximal Voluntary Isometric Contraction) of external oblique at turning motion was used for normalization of muscle activity. When the measurement of MVIC was done, participants were asked to lie on each mattress in random order. At each mattress, participants turned 2∼4 times and their EMG values were recorded (Figure 1). Prior survey showed most participants slept laterally on their left side of bodies and left body turning was studied in the study.

The study was within-subject experiment. Four different types of mattresses (latex, soft polyurethane, hard polyurethane, and memory foam) were treated as independent variable. Dependent variables were normalized external oblique activities (%MVIC) and each participant's rating for the comfort level. Score for subjective comfort was ranged between 0 and 10. The participants checked 0 when they felt very uncomfortable or selected 10 when feeling very comfortable.



(a) Back sleeping (b) Turning motion

Figure 1. Turning motion and measurement of muscle activity

Table 2. Mean muscle activity due to the mattress (%MVIC)

| Muscle | latex | soft polyurethane | hard polyurethane | memory foam |
|---|---|---|---|---|
| Right external oblique | $0.0218 \pm 0.0124$ | $0.0200 \pm 0.0093$ | $0.0228 \pm 0.0123$ | $0.0197 \pm 0.0108$ |
| Left external oblique | $0.0246 \pm 0.0130$ | $0.0202 \pm 0.0171$ | $0.0256 \pm 0.0122$ | $0.0262 \pm 0.0085$ |

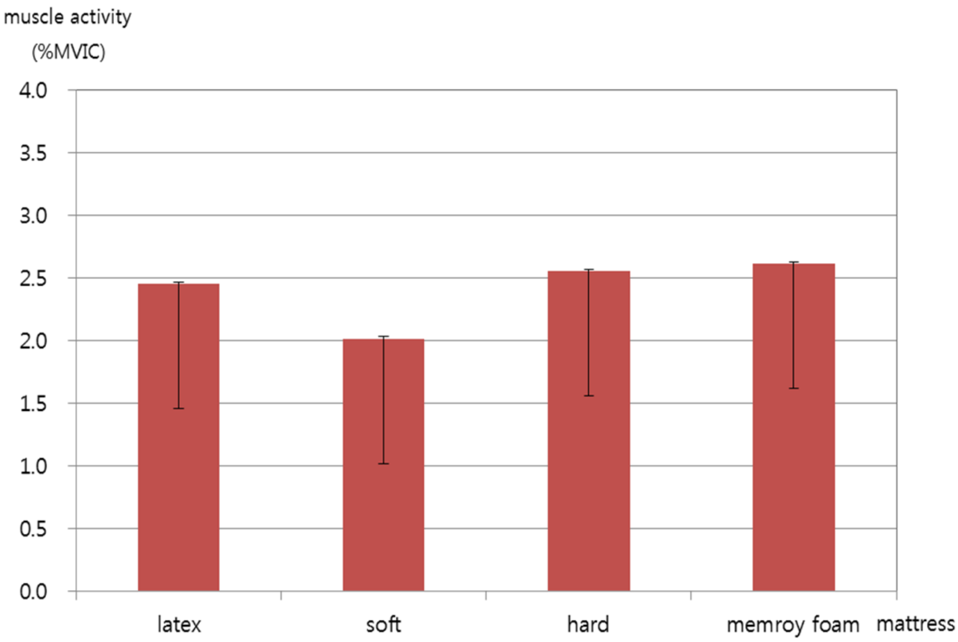



Figure 2. Mean activity of left external oblique

## 3. Results.

**3.1. Mean muscle activity.** Mean external oblique activity due to the mattress was recorded in Table 2. The mean right external oblique activity satisfied normality, but sphericity was not significant. One-way repeated measures ANOVA was conducted and significant difference was not found.

Mean activity of left external oblique satisfied normality and sphericity was significant (Wilks's $\Lambda = .76$, $F_{3,32} = 3.43$, $p < .05$). Post-hoc paired samples $t$-test was performed and significant difference between each mattress was found (Figure 2).

All mean activities of left external oblique comparisons among the mattresses were significant controlling for pairwise error rate across the tests at .01 level by using the

Holm's sequential Bonferroni procedure. The activity of left external oblique on memory foam mattress was 0.0262 ± 0.0085 (%MVIC), that of hard polyurethane was 0.0256 ± 0.0122 (%MVIC), that of soft polyurethane was 0.0202 ± 0.0171 and that of latex was 0.0246 ± 0.0130 (%MVIC).

3.2. **Peak muscle activity.** The peak muscle activity is summarized in Table 3. Both peak muscle activities of left and right external oblique satisfied normality. However, sphericity was not significant for both cases. One-way repeated measures ANOVA was performed and the difference was concluded to be not significant.

Table 3. Peak muscle activity due to the mattress (%MVIC)

| Muscle | latex | soft polyurethane | hard polyurethane | memory foam |
|---|---|---|---|---|
| Right external oblique | $10.1197 \pm 5.6133$ | $8.4661 \pm 5.1788$ | $8.1251 \pm 2.1453$ | $9.4400 \pm 5.1434$ |
| Left external oblique | $8.5869 \pm 2.3648$ | $9.1671 \pm 6.0016$ | $8.4240 \pm 3.8764$ | $9.1280 \pm 3.9828$ |

3.3. **Subjective comfort.** The subjective comfort due to the mattress is given in Figure 3. The subjective comfort at turning motion satisfied normality and sphericity was significant (Wilks's $\Lambda = .23$, $F_{3,32} = 35.55$, $p < .01$). Post-hoc paired samples $t$-test was conducted, and significant difference between each mattress was found (Figure 3).

The subjective comfort at standing motion satisfied normality, but sphericity was not significant. Thus, one-way repeated measures ANOVA was performed. Each mattress was determined to have significant difference ($F_{3,102} = 66.851$, $p < .01$).

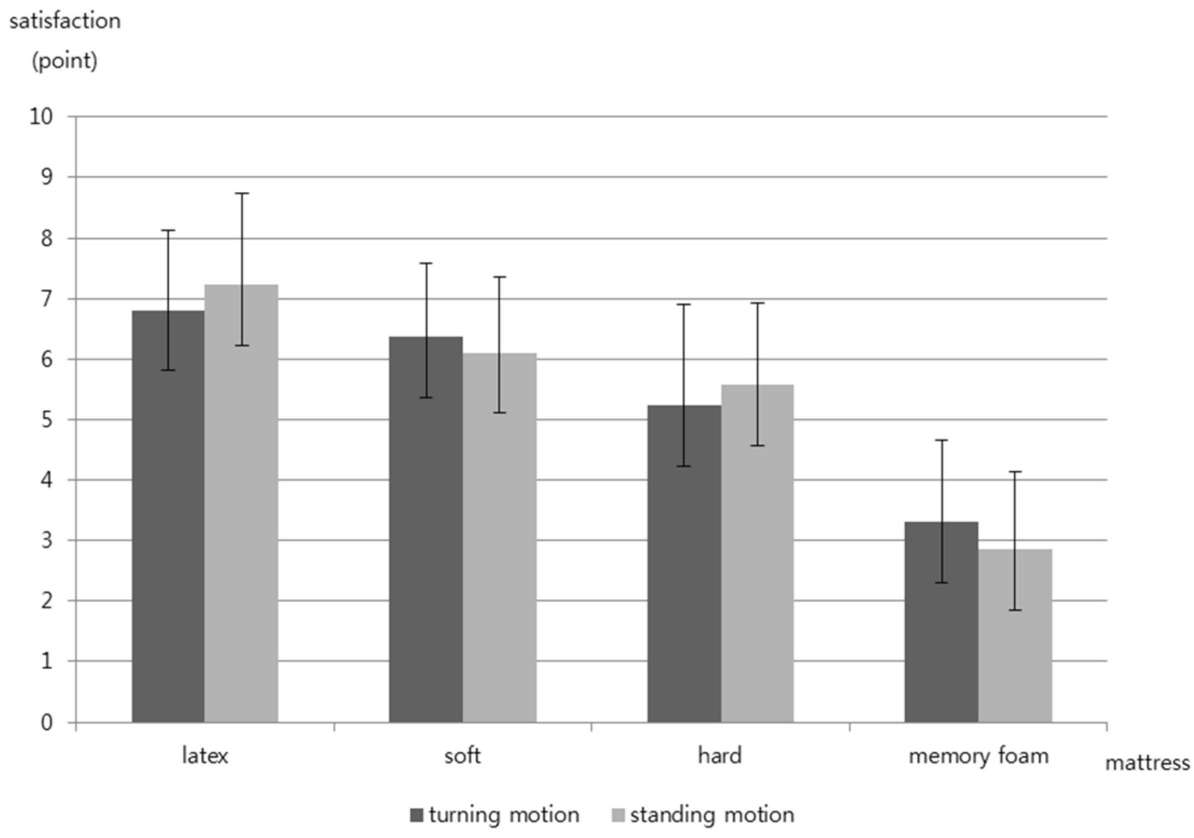



Figure 3. Subjective comfort due to the mattress

Memory foam mattress was rated as least comfortable type of mattress while in turning motion ($p < .001$). Meanwhile, no significant difference was found for subjective comfort of other mattresses. At rising motion, memory foam mattress was again rated as least comfortable ($p < .001$). According to the data, participants felt most comfortable on latex mattress while in standing up motion ($p < .001$).

4. **Conclusions.** Activity of external oblique and subjective comfort due to mattress with different motions were investigated. Peak muscle activity while turning left was highest on memory foam mattress. As a result, subjective comfort to turn left on memory foam mattress was significantly lower than other types. External oblique was least active on soft multi-hardness mattress and the rating for subjective comfort was significantly high.

In past research, mean and peak body pressure were lowest on memory foam mattress regardless of the motion. Furthermore, hard multi-hardness mattress was determined to be most uncomfortable type of mattress [9].

Mattress with low body pressure due to its softness earned high rating for subjective comfort at fixed position. However, this type of mattress caused high activity of external oblique muscle during the turning motion. Because of the high activity of the muscle, score for subjective comfort at turning motion of such mattress was significantly low.

Further studies are required to learn how muscle activity affects the quality and satisfaction of sleep. Along with it, numerical analysis for one's motion and elasticity and hardness of mattress needs to be studied. This study can be applied to developing new mattresses.

Limit of this experiment is that only the activity of external oblique was used for investigation. More meaningful results could be achieved if various motions researches are studied. The empirical results of this study can be applied to developing more comfort mattresses.

**Acknowledgment.** This research was supported by Kyungsung University Research Grants in 2018.

## REFERENCES

[1] B. Jacobson, A Boolani, G. Dunklee, A Shepardson and H. Acharya, Effect of prescribed sleep surfaces on back pain and sleep quality in patients diagnosed with low back and shoulder pain, *Applied Ergonomics*, vol.42, no.1, pp.91-97, 2010.

[2] P. Salo and P. Polo-Kantola, Sleep deprivation: Impact on cognitive performance, *Neuropsychiatric Disease and Treatment*, vol.3, no.5, pp.553-567, 2007.

[3] J. Gangwisch, S. B. Heymsfield, B. Boden-Albala, R. M. Buijs, F. Kreier, T. G. Pickering, A. G. Rundle, G. K. Zammit and D. Malaspina, Short sleep duration as a risk factor for hypertension: Analyses of the first national health and nutrition examination survey, *Hypertension*, vol.47, no.5, pp.833-839, 2006.

[4] D. J. Gottlieb, S. Redline, F. J. Nieto, C. M. Baldwin, A. B. Newman, H. E. Resnick and N. M. Punjabi, Association of usual sleep duration with hypertension: The sleep heart health study, *Sleep*, vol.29, no.8, pp.1009-1014, 2006.

[5] P. M. Krueger and E. M. Friedman, Sleep duration in the united states: A cross-sectional population-based study, *American Journal of Epidemiology*, vol.169, no.9, pp.1052-1063, 2009.

[6] M.-S. Lee, J.-S. Shin, J. Lee, Y. J. Lee, M. Kim, K. B. Park, D. Shin, J.-H. Cho and I.-H. Ha, The association between mental health, chronic disease and sleep duration in Koreans: A cross-sectional study, *BioMed Central Public Health*, vol.15, pp.1-10, 2015.

[7] J. E. Gangwisch, S. B. Heymsfield, B. Boden-Albala, R. M. Buijs, F. Kreier, M. G. Opler, T. G. Pickering, A. G. Rundle, G. K. Zammit and D. Malaspina, Sleep duration associated with mortality in elderly, but not middle-aged, adults in a large US sample, *Sleep*, vol.31, no.8, pp.1087-1096, 2008.

[8] E. M. Wickwire, J. Geiger-Brown, S. M. Scharf and C. L. Drake, Shift work and shift work sleep disorder: Clinical and organizational perspectives, *Chest*, vol.151, no.5, pp.1156-1172, 2017.

[9] C.-Y. Chun, Bedroom environment for healthy sleep, *Architectural Institute of Korea*, vol.59, no.2, pp.43-46, 2015.
[10] F.-Z. Low, M. C.-H. Chua, P.-Y. Lim and C.-H. Yeow, Effects of mattress material on body pressure profiles in different sleeping postures, *Journal of Chiropractic Medicine*, vol.16, no.1, pp.1-9, 2017.
[11] Y.-H. Kim and H.-I. Cheng, A comparative study on body pressure and subjective comfort for the mattress forms, *Journal of the Ergonomics Society of Korea*, vol.37, no.1, pp.75-82, 2018.