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Effect of Crossed-legs and Heel Sitting Postures on Median Frequency Values of Lumbar Multifidus and Internal Oblique Muscles in a Healthy Population

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Abstract

The aim of this cross-over design study was to compare the level of fatigue in the lumbar multifidus (LM) and internal oblique (IO) muscles when an individual is sitting in the crossed-legs and heel sitting postures, as measured by surface electromyography. Twenty-three subjects, aged 20 to 30 years, were asked to randomly perform the crossed-legs and heel sitting postures for 30 minutes on two occasions 24 hours apart. Median frequency (MF) data were recorded on both occasions in order to measure the muscle fatigue at seven time points (0, 5, 10, 15, 20, 25 and 30 minutes) in each sitting period. The results showed that when the subjects were in the crossed-legs sitting, the MF values of right and left LM, and right and left IO muscles were lower than those of the corresponding muscles of the heel sitting posture. These results indicated that the heel sitting posture causes less lower trunk muscle fatigue than the crossed-legs sitting posture in a healthy population during prolonged floor activity.

Keywords: lower trunk muscle fatigue, crossed-legs sitting posture, heel sitting posture

1. Introduction

Prolonged sitting posture has been shown to cause low back pain (LBP) (1-2). Furthermore, prolonged sitting with LBP is believed to be one of the most common reasons why employees will break from their focused workplace activities, leading to income loss for the employers (3).

Unsupported floor-sitting postures, especially the crossed-legs and heel sitting postures, are popular among Thai people when performing work or non-work related floor activities. These sitting postures cause less lumbar lordosis and pelvic anterior tilting than would be experienced in a standing position (4). Previous studies have shown that any back flexed posture results in substantially increased involvement of the local muscle system, including the lumbar multifidus (LM) and internal oblique (IO) muscles, to counterbalance upper compression forces on the motion of the lumbar segment and to increase lumbar stability during the sitting period (5-8). Nag and colleague (9) reported different activities of back muscle in domestic floor sitting postures; however, there is a lack of evidence supporting the LM and IO muscle fatigue in floor sitting postures, especially crossed-legs and heel sitting postures which are widely used among Thai population.

A prolonged high sitting posture could lead to LM and IO muscle fatigue due to decreases established stability performance of the two muscles, and then resulting in increase spinal compressive loads on spinal tissues, especially intervertebral disc(s) (7, 10). Increasing of spinal compressive loading for a long period of time could lead to low back pain due to increased intradiscal pressure and local muscle system fatigue (11).

A surface electromyography (sEMG) is a non-invasive and reliable method to evaluate fatigue in trunk muscles (12-14). Fatigue sustained contraction is characterized by an increased shift toward the lower end of the frequency spectrum (15). The median frequency (MF), an outcome measurement of sEMG which represents an increased spectral shift, could then be used as an indicator of muscle fatigue (14). Furthermore, the MF value has been shown to reliably and accurately detect fatigue of trunk muscles during sub-maximal muscle contraction in the early stage of a sitting period (16-17).

The aim of this study was to compare the level of fatigue in LM and IO muscles during period of sitting in the crossed-legs and heel sitting postures by examining healthy Thai men and using sEMG for measuring the median frequency values.

2. Materials and Methods

2.1 Subjects

Twenty-three healthy Thai men were recruited from the Khon Kaen University student population; the mean age of the participants was 21.6 years (standard deviation (SD) = ±2.55; range = 20-30 years), with a mean height of 168.57 cm (SD= ±4.57; range = 161-180 cm) and mean weight of 58.16 kg (SD = ±5.38; range = 50-68 kg). Individuals were excluded from study participation if they were experiencing active low back pain during the data collection period, had a history of either a spinal disorder (scoliosis, spondylolisthesis, lumbar herniated nucleus pulposus, or bamboo spine) or a neurological condition (numbness or loss of sensation at trunk and/or legs before testing), or had received lumbo-pelvic and/or abdominal surgery within 6 months prior to the data collection period. All subjects were informed verbally of the study's intent and procedures and provided signed, informed consent. The study was approved by the Ethics

Committee for Human Research of the Khon Kaen University.

2.2 Experimental protocol

This study was a cross-over study design conducted in the laboratory of the School of Physical Therapy, Khon Kaen University. The subjects were required to attend on three separate days. The first day consisted of a familiarization session. For the purpose of wash-out period of one day (18), the next two consecutive days were used for the randomized application of the two sitting postures for experimental evaluation. The order of the two sitting postures was randomly assigned using a random number sequence.

During the familiarization session, a screening questionnaire was administered to each participant in order to ensure that the subjects met the inclusion and exclusion criteria. Then, the subjects were provided with a computer-generated illustration of both sitting postures and required to practice each until they could correctly perform the two sitting postures. The entire familiarization session lasted approximately 10 minutes. On completion of the familiarization session, the subjects were excused and asked to return the next day for the subsequent test session.

During each of the two subsequent experimental sessions, the subjects were asked to lie in a supine position and rest for 10 minutes in order to eliminate any fatigue of muscles to be evaluated during the active testing period (18). For the crossed-legs sitting posture session, the subjects were asked to sit on a cushion on the floor relaxing thoracolumbar spine, slightly rotating pelvis posteriorly, hips and knees in full flexion and each leg placed so that the calf of one leg was on the top of the opposite (the foot resting on the opposite knee) and the opposite calf and foot touching down on the cushion. In addition, their hands were placed on their thighs (19). For the heel sitting posture session, the subjects were asked to sit with relaxing thorax, slightly rotating pelvis anteriorly, both hips and knees were fully flexed and contacted the cushion, and both feet were in dorsiflexion with ischial tuberosity rest on the heels. Furthermore, their hands were placed on their thighs (19). Each sitting posture was performed for 30 minutes (9). The marker of horizontal stand was adjusted to come into contact with the L3 spinous process level in order to maintain a “set” position during testing. Each subject was instructed to view a designated point set 1.5 m ahead at eye level.

2.3 Data collection and analysis

Before data collection began, the skin over the boundaries of LM and IO muscles was prepared by shaving off any hair that would obstruct the electrode sites. The sites were then cleaned with alcohol and the skin was abraded using fine sandpaper (20) to reduce its impedance to less than 5 kΩ. The subject was then attached to pairs of adhesive disposable Ag/AgCl disc surface electrodes (EL 503) with electrical contact area of one cm^2 and 2.5 cm apart from one another and parallel to muscles on both sides (7): lumbar multifidus (level of L5, parallel to an imaginary line between posterior superior iliac spine and L1-L2 interspinous space) (7, 21-23) (Figure 1) and internal oblique (medially 1 cm to anterior superior iliac spine, beneath a line joining both ASISs and just superior to the inguinal ligament) (14, 24-25) (Figure 2). Four ground electrodes were placed over both the anterior superior iliac spines and iliac crests. Snap leads were used to connect the surface electrodes and amplifiers to transfer signals, and all electrodes were secured in place with medical tape.

Surface electromyography (MP 35; Biopac Systems, California, USA) was used to continuously record sEMG signals. Raw signals were recorded at the sampling rate of 1,000 Hz. The frequency band-pass filter was set up to have bandwidth filter 500 Hz, amplifier gain×1,000, and common mode rejection ratio (CMRR) of 85 dB. In the EMG data analysis, the EMG fast Fourier transforms (FFT, where a 1-sec data epoch

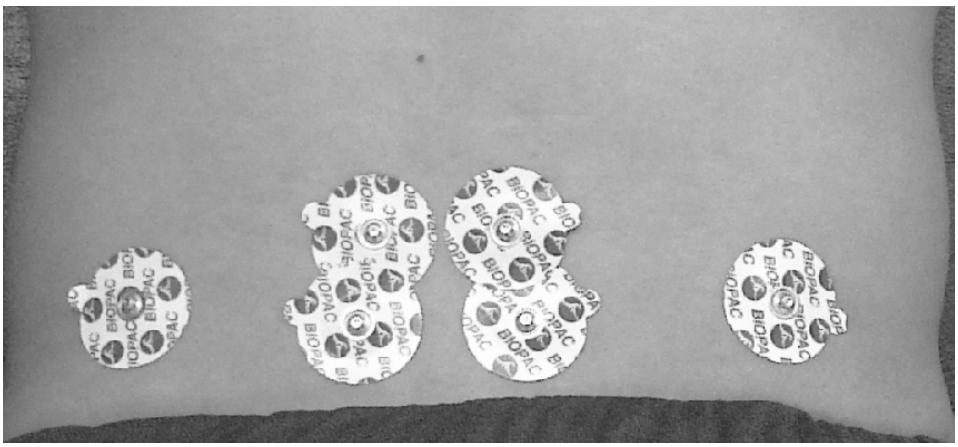

Figure 1. Surface electrode locations of right and left lumbar multifidus muscles.

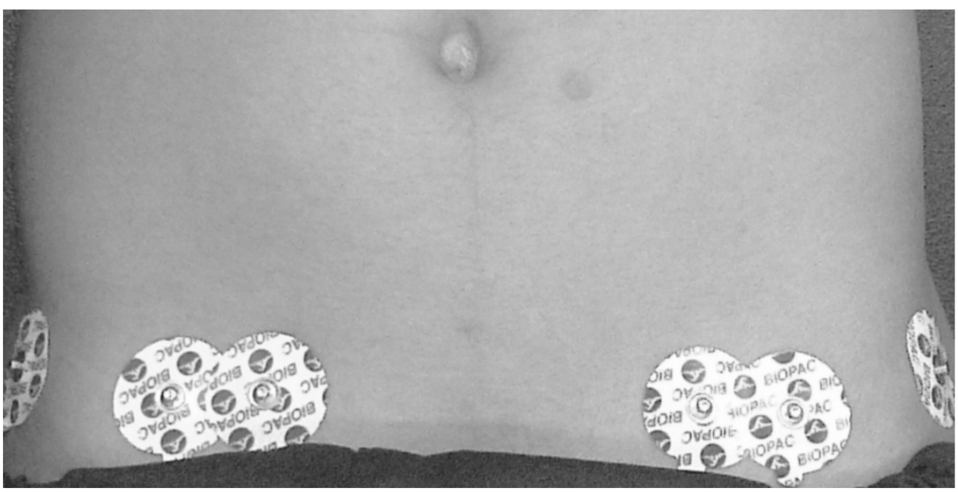

Figure 2. Surface electrode locations of right and left internal oblique muscles.

window generated 1024 data points) was used to calculate the signal spectrum (26). The MF data using FFT were calculated every five minutes throughout 30 minutes of the data collection period for both the crossed-legs and heel sitting postures.

2.4 Statistical analysis

Prior to statistical analysis, the MF data collected for each subject in each sitting posture was subjected to Kolmogorov-Smirnov test to examine for normal distribution and the result indicated that the MF data met the assumption of normal distribution. A two-way analysis of variance (ANOVA) was employed to determine the differences in MF values between the crossed-legs and heel sitting postures as measured every five minutes throughout the 30-minute period. A *P*-value of 0.05 or less was considered to be statistically significant.

3. Results and Discussion

Significant differences in MF values between the two sitting postures were shown for all the muscles measured (Table 1). The crossed-legs sitting posture had significantly smaller MF values than those from the heel sitting posture, with the mean MF over the times of measurement being 52 and 53.50 Hz in right LM muscle, 52.48 and 53.55 Hz in left LM muscle, 51.66 and 53.51 Hz in right IO muscle, and 52.54 and 54.26 Hz in left IO muscle, respectively. Times at which the measurements were recorded (0, 5, 10, 15, 20, 25 and 30 minutes) also showed significant effect on the MF value ($P<0.01$), that is, the MF value decreased over time, for all the muscles. The sitting posture × time interactions, however, were not statistically significant for all the muscles.

Comparison between MF values over time of the crossed-legs and heel sitting postures showed a continuously decline for the both sitting postures in all the muscles, with the values of the crossed-legs being lower than those of the heel sitting posture at all times (Figure 3). Interestingly, the

Table 1. Analysis of variance for median frequency (MF) measurements by surface electromyography (sEMG) of lumbar multifidus (LM) and internal oblique (IO) muscles (n = 23).

Sources	df	Right LM	Left LM	Right IO	Left IO
		MS	MS	MS	MS
Sitting Postures	1	76.585**	48.192**	111.319**	727.624**
Times	6	75.097**	23.474**	155.227**	195.145**
Sitting Postures×Times	6	0.631	3.320	0.291	2.657
Error	308	7.738	6.811	7.884	10.699
CV (%)	5.250	4.880	5.310	6.130	

Note: MS = mean square
CV = coefficient of variation
** $P < 0.01$

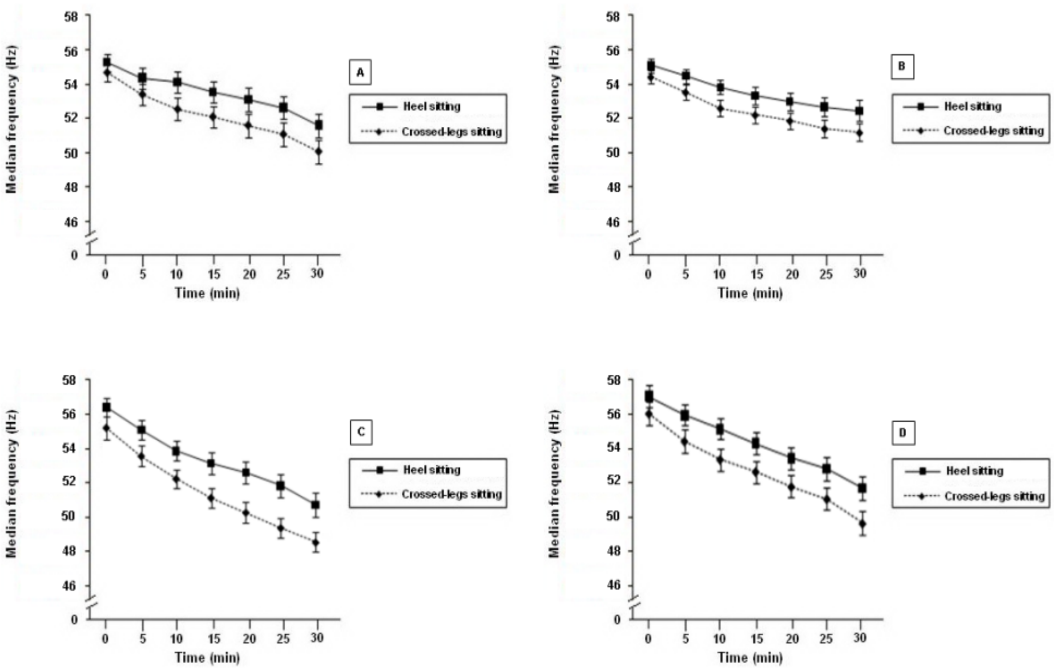

Figure 3. Mean and standard error (SE) of median frequency for the right lumbar multifidus muscle (A), left lumbar multifidus muscle (B), right internal oblique muscle (C) and left internal oblique muscle (D) throughout 30 minutes between the crossed- legs sitting and heel sitting postures.

difference between the MF values for the two sitting postures occurred immediately at the beginning of the measurement time in all the muscles, with the MF values of the heel sitting posture being higher than those of the crossed-legs sitting posture, although these differences were not quite significant statistically. These differences, however, increased over time and became statistically significant from five minutes onwards. In addition, the interactions between the sitting postures and times were not significant statistically.

This current experiment is a novel study comparing the LM and IO muscle fatigue between the crossed-legs and heel sitting postures in a healthy population. The results revealed that the MF values of right and left LM, and right and left IO muscles in the crossed-legs sitting posture were lower than those of the heel sitting posture. For both sitting postures, the MF values significantly declined over time throughout 30 minutes in all the muscles, but the rate of decline appeared to be slightly faster and consequently making the value reaching a certain level faster for the crossed-legs sitting posture. It could be a reason in biomechanics for choosing sitting posture during prolonged working on the floor.

Although the crossed-legs and heel sitting postures are both symmetrical floor sitting postures, they show the different positioning of the trunk. LM and IO muscles may contract with different force levels to maintain the sitting position. O'Sullivan et al

(7) proposed that the difference of trunk position among several unsupported sitting postures could provide the distinction of LM and IO muscle activations. Thus, biomechanical aspect of the trunk position could influence to lower trunk muscle fatigue (27).

The current findings clearly demonstrated that the crossed-legs sitting posture had lower MF values than those of the heel sitting posture since the beginning, and the value also appeared to show a higher level of declination of fatigue in all the muscles than the heel sitting posture. The reasons for supporting these findings are based on the observing each sitting posture. The hip joints were approximately in 90 degrees flexion and along with fully external rotation in the crossed-legs sitting posture that may result in pelvic posteriorly rotated and lean trunk forward (28). In this sitting posture, decreasing of lordotic curve of the lumbar spine could be observed. It is recognized that LM and IO muscles have an important stabilizing role on the lumbo-pelvic region for reducing stress on the inert tissues (29-30). If the LM muscle is passively stretched by increasing of the forward trunk, then this muscle should increase its force to maintain equilibrium and stability of the lumbar spine of sitters (31) and also increasing IO muscle activity to balance forces with the LM muscle (7). Therefore, this would induce higher fatigue of the LM and IO muscles in the crossed-legs sitting posture.

Unlikely to the crossed-legs sitting posture, the heel sitting posture provides less flexion of the hip joints in the heel sitting posture may result in slightly pelvic anteriorly rotated and more trunk erection. It could be described as a near-neutral sitting posture. To maintain the upper body weight, LM and IO muscles may contract with subtle force for maintain this sitting posture. Interestingly, higher MF at the beginning of this sitting posture may be described by the effects of muscle length and recruitment patterns of muscle fiber types. The LM muscle in the crossed-legs sitting posture may be passively stretched by trunk forwardly and increase recruitment of type II muscle fibers when compared with the heel sitting posture which is shorter LM muscle length and preferential recruitment of type I muscle fibers. These are supported by previous studies (32-34) that decrease muscle length and increase recruitment of type II muscle fibers during task position relate to lower MF at the beginning period. As the lumbo-pelvic curvature plays an important role in achieving and maintaining any sitting posture, further study is needed to evaluate its association with the LM and IO muscles fatigue during the crossed-legs and heel sitting postures.

De Luca (35) stated that some factors could affect to the EMG signal, such as skin impedance, subcutaneous tissue dept. According to these, this study has tried to control each factor. For example, this study has attempted to minimize the effect of skin impedance by decreasing skin impedance less than 5 kΩ. To control the effect of subcutaneous tissue dept, this study recruited the subjects who had only normal body mass index for participation. Therefore, some factors as mention above may not affect to the correction of the finding of this study.

The current study design was a cross-over design. When compared to a parallel design study, a cross-over design can yield a more efficient comparison than a parallel design, such as fewer subjects may be required in order to attain the same level of statistical power, precision and to reduce the within-subject variation (36). The previous study suggested that the fatigability of muscles could be reversed to a normal stage in 10 minutes (18). Thus, the study design had an adequate wash-out period to minimize any carry over effects in each sitting posture. Moreover, the sequence of subjects' allocation to each sitting posture in the current study has been balanced. Thus, the study is a robust study and could provide reliable results.

It should be noted that the study presented herein focused on trunk muscles fatigue during the crossed-legs sitting and heel sitting postures without concern about trunk and lower extremities discomfort that may also have contributed to the LM and IO muscles fatigue. Further study in this point is warranted. Additionally, we acknowledged that this study measuring the fatigue of LM muscle using surface electrodes may be confounded by crosstalk with erector spinae muscle.

Although, the heel sitting posture caused less LM and IO muscles fatigue, it may not be an appropriate choice for individuals with overweight or pain in lower extremity due to this posture could provide greater compressive load to the knee and ankle joints.

4. Conclusion

In conclusion, this study suggests that the heel sitting posture would be a good choice for prolonged floor sitting posture. The heel sitting posture causes less lower trunk muscle fatigue than the crossed-legs sitting posture in a healthy population, and is superior during prolonged floor activity.

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