

## Leg Crossing-Induced Asymmetrical Trunk Muscle Activity During Seated Computer Work

**Yeon-gil Chung, M.Sc., P.T.**

Dept. of Physical Therapy, The Graduate School, Hanseo University

**Yong-wook Kim, M.Sc., P.T.**

**Jong-hyuck Woen, M.Sc., P.T.**

Dept. of Rehabilitation Medicine, Wonju Christian Hospital

**Chung-hwi Yi, Ph.D., P.T.**

**Hye-seon Jeon, Ph.D., P.T.**

**Oh-yun Kwon, Ph.D., P.T.**

Dept. of Physical Therapy, College of Health Science, Yonsei University

### Abstract

Cross-legged sitting postures are commonly assumed during computer work. The purpose of this study was to determine the effects of leg crossing on trunk muscle activity while typing at a computer. Trunk muscle activity was measured in three 8 different sitting postures, in random order. These posture were: normal sitting with a straight trunk and both feet on the floor (NS), upper leg crossing (ULC), and ankle on knee (AOK). The right leg was crossed onto the left leg in both cross-legged postures. Twenty able-bodied male volunteers participated in this study. Subjects typed on a computer keyboard for one minute. Surface electromyography (EMG) was used to record bilateral muscle activity in the external oblique (EO), internal oblique (IO), and rectus abdominis (RA). The EMG activity of each muscle in the NS posture was used as a reference (100% EMG activity) in relation to the two cross-legged postures. Muscle activity in the right EO, right IO, and left IO was significantly lower in the ULC posture than in the NS posture. In contrast, muscle activity in the right RA was significantly higher in the ULC posture than in the NS posture. Muscle activity in the right RA was significantly higher in the AOK posture, as compared to the NS posture, whereas activity in the left IO was significantly lower in the AOK posture, as compared to the NS posture. The right-left muscle activity ratios in the EO and IO showed significantly different patterns in the cross-legged postures, suggesting that asymmetrical right-left oblique muscle activity had occurred.

**Key Words:** Computer work; Cross-legged sitting postures; Electromyography; Trunk muscle.

### Introduction

Previous studies have shown that computers are used by more than 25% of the workforce for more than half of the working hours (Hjelm et al, 2000). As labor involving office automation terminals increases, musculoskeletal pain or disorders related to computer use are also increasing (Aaras et al, 1997; Armstrong et al, 1994; Bergqvist et al, 1995; Faucet

and Rempel, 1994). Because higher stress is applied to the vertebrae in a seated position, as compared to a standing position, workers who are required to sit for prolonged periods have an increased risk of lower back pain (Donald et al, 1999). To maintain a proper sitting posture, balanced trunk muscle force and muscular endurance are required (Neumann, 2002). Balanced bilateral activity in the external oblique (EO) and internal oblique (IO) muscles is essential to

align the trunk properly. Because the function of these muscles is to control the rotation of the trunk, symmetrical muscle activity is critical to maintain an upright sitting posture (Bergmark, 1989). Although most people understand that maintaining a correct posture can minimize back problems, forward head posture, kyphotic posture, and leg crossing are frequently assumed when sitting for an extended period.

It has been suggested that leg crossing occurs to equalize seated pelvic height when there is a difference in leg length (Pinar et al, 2004). However, it is most likely that leg crossing occurs because of comfort or habit. The lumbar spine is relatively resistant to vertical stress; however, it is vulnerable to rotation or bending stress. Leg crossing can induce asymmetrical body posture and pelvic rotation secondary to hip joint flexion, thus increasing the rotation moment at the vertebrae (Andersson et al, 1975).

Very few studies have been published on the effect of leg crossing on trunk muscle activity. Cross-legged sitting has been advocated based on the results of previous studies. Snijders et al (1995) reported that cross-legged sitting with the use of a backrest and armrests is physiologically beneficial because it decreases EO and IO muscle activity, resulting in reduced fatigue. It was also reported that leg crossing stabilizes the sacroiliac joint, which induces hip joint adduction in people with sacroiliac joint instability (Snijders et al, 2004). The elongation of the piriformis muscle as a result of leg crossing may be functional in the build-up of tension between the sacrum and the femur in vitro (Snijders et al, 2006). These findings indicate that cross-legged sitting should be incorporated when designing an ergonomically correct working environment for seated workers.

However, these studies did not investigate the effect of leg crossing during functional activities, and subjects were able to lean against backrests, which confounded muscle activity measurement. In industrial worksites, chairs without backrests or arm-

rests are used. We think that understanding the effect of cross-legged postures on trunk muscle activity during functional activities, while seated in a chair without additional support, would provide useful information for computer users. Our objective was to compare bilateral muscle activity in the EO, IO, and rectus abdominis (RA) muscles while typing on a computer keyboard in three different sitting positions.

## Methods

### Subjects

Twenty healthy, male, university students volunteered to participate in this study. Subjects were able to type without looking at the computer keyboard. The subjects characteristics are summarized in Table 1. The exclusion criteria were lower extremity deformity, severe orthopedic or neurological disease, trauma during the previous six months, or pain in the lower extremities. Each subject's range of motion was assessed to exclude subjects with stiffness in the hip or knee muscles. Before the study, the principal investigator explained the procedures to the subjects in detail. All the subjects signed an informed consent form approved by the Human Studies Committee of the College of Health Sciences at Yonsei University, Korea.

**Table 1.** Subjects characteristics (N=20)

Parameters	Mean±SD	Range
Age (yrs)	23.8±2.1	20~28
Stature (cm)	172.9±4.1	164~179
Whole body mass (kg)	65.5±5.7	56~78

### Instrumentation

Electromyograph (EMG) data were collected using a Biopac MPI00WSW<sup>1)</sup> and a Bagnoli EMG System<sup>2)</sup>. DE-3.1 double differential electrodes with

1) Biopac Systems Inc., Goleta, CA, U.S.A.

2) Delsys Inc., Boston, MA, U.S.A.

an inter-electrode distance of 10 mm<sup>3)</sup> and a reference electrode were used. The EMG signals were amplified and digitized using Acqknowledge 3.7.2 software (Biopac Systems Inc., Goleta, CA, U.S.A.). The sampling rate was 1024 Hz. Bandpass (20~450 Hz) and bandstop filters (60 Hz) were used. The raw data were processed into the root mean square (RMS) and then converted into ASCII files for analysis.

### Electrode Placement

To prepare the electrode sites, the skin was shaved and cleaned with rubbing alcohol. The reference electrode was attached to the styloid process of the ulna on the dominant upper extremity. EMG data were collected for the following muscles on both sides: EO, on the inferior edge of the 8th rib, superolateral to the costal margin; IO, in the horizontal plane, 2 cm medial to the anterior superior iliac spine; RA, parallel to the muscle fibers on the back of the thigh, approximately half the distance from the gluteal fold to the back of the thigh (Crams et al, 1998).

### Experimental Procedure

EMG data were collected in the normal sitting with a straight trunk and both feet on the floor (NS), upper leg crossing (ULC), and ankle on knee (AOK) postures while subjects typed at a keyboard for one minute. In the NS posture, the subject was instructed to straighten the trunk and place both feet on the ground. Then, the subject was instructed to cross his right leg onto his left leg in two cross-legged postures. The computer monitor and keyboard were stabilized in the same position while typing. The order of leg crossing was randomized. A 5-min resting period was permitted after each posture.

### Statistical Analysis

EMG data were recorded for 40 s, which excluded the initial and final 10 s of the task. To normalize the data, the EMG signals collected during the ULC and AOK postures were expressed as a percentage

of the muscle activity during the NS posture. The right-left muscle activity (right muscle activity divided by left muscle activity) in the EO and IO in the ULC and AOK postures was calculated as a ratio of the right-left muscle activity in the EO and IO in the NS posture.

### Statistical Analysis

The data are expressed as the mean  $\pm$  standard deviation. One-way ANOVA with repeated measures were used to detect significant differences in the activity of each muscle for the sitting postures, and the right-left muscle activity ratios for the EO and IO. The Bonferroni test was used to make post hoc comparisons. The level of significance was set at .05.

## Results

### Muscle Activity in Different Sitting Positions

The muscle activity recorded during computer work in different sitting postures is presented in Table 2. There were significant differences in muscle activity in the right EO, right IO, right RA, and left IO (Table 2). Muscle activity in the right EO, right IO, and left IO was significantly lower in the ULC posture than in the NS posture, whereas muscle activity in the right RA was significantly higher in the ULC posture, as compared to the NS posture. Muscle activity in the right RA was significantly higher in the AOK posture than in the NS posture, whereas activity in the left IO was significantly lower in the AOK posture than in the NS posture. There were also significant differences in the right EO between the ULC and AOK postures.

### Right-Left Muscle Activity Ratio in Different Sitting Positions

The right-left muscle activities in the EO and IO are presented in Figures 1 and 2. The right-left muscle activity ratio in the EO was significantly

3) Delsys Inc., Boston, MA, U.S.A.

**Table 2.** The mean of muscle activity during the computer work in different sitting position

Muscle	Sitting postures		
	NS <sup>a</sup>	ULC <sup>b</sup>	AOK <sup>c</sup>
Right external oblique	100.00±.00	74.77±32.98*	104.48±41.66 <sup>†</sup>
Right internal oblique	100.00±.00	53.01±41.23*	75.20±77.10
Right rectus abdominis	100.00±.00	111.64±16.76*	113.60±18.52**
Left external oblique	100.00±.00	83.88±28.65*	85.37±29.89
Left internal oblique	100.00±.00	68.64±27.17*	69.51±27.75**
Left rectus abdominis	100.00±.00	100.58±9.00*	98.17±7.98

<sup>a</sup>NS: normal sitting with straight trunk and both feet on the floor.

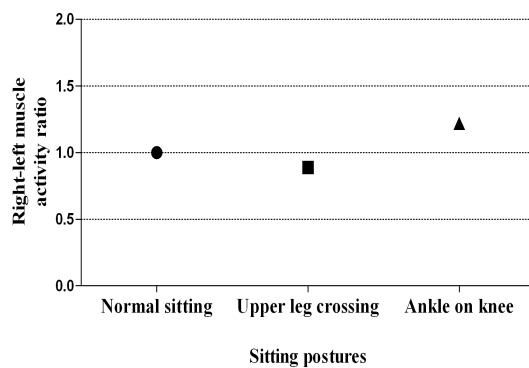
<sup>b</sup>ULC: upper leg crossing.

<sup>c</sup>AOK: ankle on knee.

\*Significant difference between NS and ULC at level of  $p < .05$ .

\*\*Significant difference between NS and AOK at level of  $p < .05$ .

<sup>†</sup>Significant difference between ULC and AOK at level of  $p < .05$ .

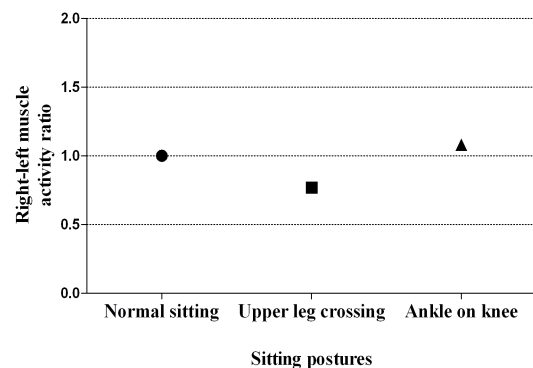


**Figure 1.** The mean of right-left external oblique muscle activity ratio in different sitting postures.

higher in the AOK posture than in the NS posture ( $p < .05$ ). The right-left muscle activity ratios were significantly lower in the ULC and AOK postures than in the NS posture ( $p < .05$  for both comparisons).

### Discussion

It is difficult to maintain a good sitting posture during prolonged computer work (Carter and Bainster, 1994). This inability can induce musculoskeletal pain and increase the rotation moment to the vertebral column as a result of pelvic rotation



**Figure 2.** The mean of right-left internal oblique muscle activity ratio in different sitting posture.

(Schamberger, 2002). When the legs are crossed, lumbar flexion is increased to compensate for insufficient hip flexion range, and pelvic rotation increases the rotation moment in the lumbar area (Callaghan and McGill, 2001). Musculoskeletal pain occurs because of the change in muscle length when assuming an incorrect posture for a prolonged period and performing repetitive movements (Bergqvist et al, 1995). Nachemson and Elfstrom (1970) reported that two-fold loading was applied to the L3 intervertebral disc in rotation, with the trunk flexed in a sitting position, as compared to a standing position. This might indicate that the risk factor increases ac-

ording to the rotation moment in the lumbar vertebral column when working at a computer in a flexed sitting position.

Previous researchers reported that trunk muscle activity decreased in cross-legged postures, as compared to postures with both feet on the floor (Snijders et al, 1995). These results suggest that leg crossing is physiologically beneficial because it reduces fatigue during prolonged sitting. However, it is possible that cross-legged sitting can produce trunk muscle asymmetry and asymmetrical muscle length change in the EO and IO. We compared trunk muscle activity in three different sitting positions. We found that activity in the right EO and IO decreased significantly in the ULC posture, as compared to the NS posture ( $p < .05$ ), and that activity in the left IO decreased significantly in the ULC and AOK postures, as compared to the NS posture ( $p < .05$ ). These findings are consistent with those described by Snijders et al (1995). However, muscle activity in the right RA increased significantly in the ULC and AOK postures, as compared to the NS posture ( $p < .05$ ). This is in contrast with the findings of Snijders et al (1995), in which RA muscle activity was insignificant. The RA acts as a trunk flexor; this muscle originates from the pubic crest and symphysis pubis and inserts into the xiphoid process and the cartilage of the 7th to 9th ribs. We think that the significant increase in activity in the right RA in the ULC and AOK postures is caused by trunk flexion, or, that the flexor moment increased during leg crossing.

Contradictory to the interpretation of Snijders et al (1995), decreased muscle activity in the EO and IO during leg crossing could cause malaligned posture. In addition, this asymmetrical muscle activity could result in muscle length change, and induce rotational deformity. Richardson et al (1999) demonstrated that decreased activity in the muscles that maintain posture, such as the erector spinae and abdominal muscles, increases loading on bones and ligaments. Thus, the maintenance of sitting postures depend upon

passive structures, not on active muscle contraction. Considering the fact that the lumbar spine is an inherently unstable structure, trunk muscles should be activated symmetrically to bilaterally support the spine without axial rotation. Therefore, decreased EO and IO activity might impose an abnormal stress on the musculoskeletal structure, resulting in musculoskeletal pain.

The right-left muscle activity ratios in the EO and IO were significantly different in the ULC and AOK postures, as compared to the NS posture. This difference indicates that leg crossing induced asymmetrical activity in the right-left oblique muscles, which control rotation of the trunk. Muscles function at their optimum when muscle length is maintained in a correct length-tension relationship (Caiizzo, 2002). During prolonged seated computer work, it is difficult to sustain a correct posture. Thus, faulty postures such as leg crossing are often assumed. This postural fault can change muscle length and, therefore, muscle strength. Imbalanced stiffness and shortening of the right-left obliques can cause trunk asymmetry by limiting lumbar rotation in one direction and increasing lumbar rotation in the other direction (Panjabi, 1992). According to the concept of directional susceptibility of movement, movement in one direction is encouraged at the lumbar joint when the legs are crossed (Sahrmann, 2001). Rather than preventing muscle fatigue as a result of reduced trunk muscle activity, leg crossing induces asymmetrical movement, which leads to musculoskeletal pain and injury. The prolonged inhibition of postural muscle activity during daily activities can cause disuse atrophy. If an individual habitually crosses his or her leg to one side, it may cause weakness of the IO and EO on that side. IO and EO muscles are essential to maintain an upright position without lumbar rotation. Muscular weakness on one side can cause lumbar rotation, which is evident in spinal scoliosis.

Although the aim of occupational ergonomics is to prevent musculoskeletal diseases in the workplace, success has been limited in that individual anthro-

pometric properties cannot be accommodated. In our opinion, assuming and maintaining a biomechanically correct posture is the most important factor in the prevention of musculoskeletal disease.

This study has a number of limitations. First, the rotation moment or pressure applied to the the lumbar vertebrae while maintaining a cross-legged posture was not measured directly. Instead, we measured bilateral muscle activity in the EO and IO. EMG measures the load applied to the muscle of interest, even though a change in muscle activity cannot be interpreted as a muscle action (Nordander et al, 2000). Second, this study was conducted in a laboratory rather than a real work environment. Third, the effect of leg crossing on deep stabilizing muscles in the trunk, such as the transversus abdominis and the multifidus, was not examined. These points set limitations on our ability to generalize the findings of this study. Further studies are warranted to investigate the response of deep muscles to cross-legged postures and the long-term effects of habitual leg crossing.

### Conclusions

In general, our results showed that crossing the right leg onto the left leg decreased activity in the EO and IO muscles, and increased activity in the RA, as compared to the neutral posture. The right-left EO and IO activity ratios were also significantly different in cross-legged postures, as compared to the neutral posture, indicating that right-left muscular asymmetry had occurred.

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