

## **CHAPTER V**

### **DISCUSSION**

This is the novel study to evaluate the effect of sitting posture on the fatigability of lumbar multifidus (LM) and internal oblique (IO) muscles, including lower trunk discomfort, and the correlation between the fatigability and lower trunk discomfort. The current study clearly reveals that there are significant differences in normalized MF slope in LM and IO muscles, that is, the crossed sitting posture is defined by greater fatigability of LM and IO muscles when compared to the heel sitting posture. There were no statistical significant differences of lower trunk discomfort using visual analogue scale (VAS) between the two sitting postures. However, correlations between normalized MF and VAS demonstrated significant great negative correlations.

#### **1. The fatigability of lumbar multifidus (LM) and internal oblique (IO) muscles between the crossed sitting and heel sitting postures**

Changes of the normalized MF slope of LM and IO muscles occurred in the crossed sitting and heel sitting postures. Nevertheless, there was greater fatigue of LM and IO muscles in the crossed sitting posture when compared to the heel sitting posture (Table 2). van Dieën et al. (1997) studied the effect of kneeling posture and seated posture on the fatigability of LM muscles. Their results showed normalized MF slope in the kneeling posture (left LM muscle = -0.00049 %/second, right LM muscle = -0.00046 %/second) and in the seated posture (left LM muscle = 0.00002 %/second, right LM muscle = 0.00033 %/second). However, the current result demonstrated normalized MF slope in the crossed sitting posture (right LM muscle = -0.144 %/second, left LM muscle = -0.138 %/second) and in the heel sitting posture (right LM muscle = -0.105 %/second, left LM muscle = -0.106 %/second). The greater normalized MF slope in the current study when compared to the study of van Dieën et al may be due to differences of sitting postures and characteristic activities of muscles. The sitting tasks in the study of van Dieën et al were designed to simulate

postures and movements occurring during harvesting of radishes. Then, they were more likely dynamic sitting postures when compared to the sitting postures in the current study. The previous study proposed that lack of trunk motion leads to an accumulation of metabolites (Pope et al., 2002). Furthermore, the dynamic task shows less electromyographic data of paravertebral muscle fatigue, probably due to the dynamic paravertebral muscle contraction pattern (Hansen et al., 1998). Therefore, these reasons may support the greater fatigability of LM muscles in the current study when compared to the study of van Dieën et al. However, the fatigability of IO muscles during floor sitting is not reported. The current study is the novel study to measure the fatigability of the IO muscles during floor sitting posture. Although the crossed sitting and heel sitting postures are symmetrical floor sitting postures, the current result shows inequality of the LM and IO fatigue. This may be caused by differences of center of gravity location due to differences of trunk postures. The unequal alteration of trunk postures in different unsupported sitting postures can preferentially facilitate different lumbo-pelvic stabilizers activation in LM and IO muscles (O'Sullivan, 2000; O'Sullivan et al., 2006). Moreover, the previous study (van Dieën et al., 1997) stated that the activation of lower back muscles, especially LM muscles was highly related to their fatigability. Thus, biomechanical differences between trunk posture can affect different lumbo-pelvic muscle fatigue (Champagne et al., 2008).

The current study concerned an optimal sitting posture which was to relax the thorax and receive the lumbar neutral lordosis for the crossed sitting and heel sitting postures. It results in minimize connective tissue strain (Macintosh et al., 1993). Furthermore, it preferably activates LM and IO activities to provide a lumbo-pelvic stability without a high compressive load on the lumbar spine (Kavcic et al., 2004). Nevertheless, when observing subjects during the sitting period, there was a difference of lumbo-pelvic posture between the crossed sitting and heel sitting postures. It may be speculated that there is no advantage to the optimal sitting posture. Therefore, two sitting postures may have difference of center of gravity location. The heel sitting posture may have more trunk erection than in the crossed sitting posture. Thus, the heel sitting posture may have a mechanical advantage for the LM and IO muscles since the center of gravity may posteriorly pass near the fulcrum of the

lumbar spine. This sitting posture may be assumed near the neutral sitting posture. Moreover, the heel sitting posture may produce less flexor moment arm of upper body when compared to the crossed sitting posture. In addition, the muscle activations in a neutral position under upper body load may exhibit a small recruitment pattern in local muscles, especially LM and IO muscles to maintain an equilibrium posture (Kiefer et al., 1998). Furthermore, the EMG study showed that the EMG signal levels recorded from the trunk muscles in a neutral posture or slightly neutral posture were very low (Cholewicki et al., 1997). Therefore, these causes may indicate that the heel sitting posture shows less fatigue of LM and IO muscles than the crossed sitting posture.

On the other hand, the crossed sitting posture has flexion of the hip joint of approximately 90 degrees and external rotation of hip joint when compared to the trunk. The effect of hip position of the crossed sitting posture may cause subjects to adopt forward trunk posture (Shin et al., 2009). This trunk posture of the crossed sitting posture may be a cause of greater muscle fatigue development when compared to the heel sitting posture. This is because the line of thrust from the center of gravity passes in front of the spine and ischial tuberosities (Harrison et al., 1999). It may result in increasing flexor moment arm. The LM muscles, passively stretched by inclination of forward trunk in the crossed sitting posture, must increase their tension to exert a pull on the lumbar spine to resist the increase of flexor moment arm, to maintain the equilibrium of the sitting posture and prevent the sitter folding forward (Corlett, 2008). This reason may be a cause of LM fatigue in the crossed sitting posture. Additionally, the IO muscles may respond to increase their co-contracted activities to balance forces with back muscles (O'Sullivan et al., 2006) and may result in greater IO fatigue in the crossed sitting posture. When compared to the heel sitting posture, the crossed sitting posture had a mechanical disadvantage and produced greater fatigability of LM and IO muscles.

Although the anatomical regions may overlap between internal oblique (IO) and external oblique (EO) muscles, the previous study suggested that the attached area in the current study is very amenable to detecting clear IO signals (O'Sullivan et al., 2006). Each IO muscle was tested for its action. When performing trunk rotation to one side of the IO muscle, the IO muscle on the same side of rotation showed a

greater EMG signal but the IO muscle at the opposite side showed a silent EMG signal. Thus, there is no a cross-talk of EO muscles. Unfortunately, the current study did not investigate the lumbo-pelvic curvature between the two sitting postures. Therefore, further study should evaluate the LM and IO fatigue including the lumbo-pelvic curvature in the crossed sitting and heel sitting postures. Furthermore, the current study could not explain the fatigability of LM and IO muscles using their muscle activities data due to LM and IO muscle activities were not measured. Then, further study should investigate the LM and IO muscle activities along with their fatigue.

## **2. The lower trunk discomfort between the crossed sitting and heel sitting postures**

The subjective discomfort assessment using VAS in the current study exhibited the significant effect of time on VAS, that is, the magnitude of VAS increased from zero to 30 minutes for both sitting postures (Table 4 and Figure 11). The current finding was supported by the study of van Dieën et al (1997). They proposed that changing of the back discomfort significantly increased with time throughout three hours testing period. They found that back discomfort significantly increased with time throughout three hours testing period. They explained that the increase of trunk discomfort over the testing period may be due to metabolite accumulation (Clark et al., 2003; Allen, 2008) or neuromuscular impairment (Sacco et al., 1994; Maffiuletti and Lepers, 2003; Desbrosses et al., 2006; Lee et al., 2007). Therefore, static muscle activation in prolonged sitting postures may become a source of postural discomfort and lower back pain (Todd et al., 2007).

Although time showed a significant effect on VAS, there was no interaction between time and sitting posture and no significant difference of VAS between the crossed sitting and heel sitting postures. The lack of statistical significant difference of VAS between the two sitting postures may be due to an inadequate time of testing period. Further study may need a longer testing period to evaluate the effect of the crossed sitting and heel postures on lower trunk discomfort.



### **3. The correlation between the normalized median frequency (normalized MF) and visual analogue scale (VAS)**

This is the first study to evaluate the correlation between normalized MF and VAS. The correlation between the normalized MF and VAS in the current study exhibited a great significant negative correlation ( $r \geq -0.88$ ,  $p < 0.01$ ) in the four muscles. The normalized MF is an outcome measurement of sEMG to investigate fatigability of muscles and has a high accuracy to detect muscle fatigue at an early stage (Mannion et al., 1997; Roy et al., 1997; De Luca, 1997; Sparto et al., 1997). Dederling et al. (1999) proposed that the EMG median power frequency slopes showed moderate correlation with the Borg rating scale. Callaghan et al. (2009) stated that the discomfort assessment tool VAS had poor significant correlation with objective assessment when they assessed the discomfort by using VAS and near-infrared spectroscopy (NIRS) ( $r = 0.07-0.47$ ). There was no study to investigate the correlation between normalized MF and VAS. Thus, a good correlation between normalized MF and VAS in the current study may be speculated as a reliable method to assess the LM and IO fatigue. It can be inferred that when subjects felt a greater lower trunk discomfort, the LM and IO muscles may realistically fatigue.

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 (Nanta and Patumanond, 2008). The previous study suggested that the fatigability of muscles could be reversed to a normal stage in 10 minutes (Jones et al., 2004). 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 sequence of sitting posture did not affect to the results.

The current study shows that the crossed sitting posture can produce greater fatigue of LM and IO muscles than the heel sitting posture. In addition, increasing lower trunk discomfort can happen with increasing time, however, there was no a statistically significant difference of VAS between the two sitting postures. The

correlation between normalized MF and VAS showed highly significant negative correlation.

#### **5.4 Research limitations**

There are a few limitations in the current study. Firstly, it is important to note that the findings of the current study investigate the fatigability of only trunk muscles. Therefore, it cannot reflect the fatigability of other areas. Secondly, suffering pain or numbness in the legs during a sitting period may disturb LM and IO fatigue and discomfort as it may contribute to dissatisfaction of the subjects and this may confound the findings. Further study should investigate fatigability and discomfort of both trunk and leg muscles. Finally, the current study cannot answer that the lower trunk discomfort of the subjects influences form central fatigue mechanism or peripheral fatigue mechanism. Therefore, it would be worth for a further study to discriminate what is a cause of lower trunk discomfort when being in the crossed sitting and heel sitting postures.