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The purpose of this study was to assess trunk muscle fatigue in seated handicraft tasks using surface electromyography (sEMG) and visual analogue scale (VAS) ratings for trunk discomfort, and to assess the relationship of these responses. Twenty-three participants were randomly assigned to assumed crossed-leg and heel sitting postures for 30 min. Normalised median frequency (NMF) slopes for lumbar multifidus (LM) and internal oblique (IO) muscles and VAS ratings were recorded. Results revealed that the crossed-leg posture produced significantly steeper NMF slopes for both sides of the LM and IO muscles than heel sitting. Greater VAS ratings were found in crossed-leg sitting posture than the heel sitting posture. The NMF slopes and the VAS ratings had significant negative correlations for both postures. Findings support heel sitting in handicraft tasks over crossed-leg sitting due to greater trunk muscle fatigue and discomfort during the latter posture. Results support VAS ratings as a complementary method to sEMG for identifying trunk muscle fatigue.

Practitioner Summary: Trunk muscle fatigue in handicraft work is a potential risk for low back pain. Based on EMG and discomfort analyses, heel sitting is preferred to crossed-leg posture. Discomfort ratings are consistent with EMG measures in identifying trunk muscle fatigue in such postures.

Keywords: trunk muscle fatigue; body discomfort; surface electromyography; visual analogue scale; normalised median frequency slope

1. Introduction

Handicraft work is one of the major export products in Southeast Asia, including Thailand. In 2005, it was estimated that approximately 1.08 million Thai people worked in domestic or cottage industries making handicrafts (Office of the National Economic and Social Development Board 2009). Of these persons, 54.3% are males (Teeratrakul *et al*. 2009). Due to the nature of work tasks in these industries and the available workstation resources, workers use floor-sitting postures and are not likely to use chairs or western sitting styles. Floor sitting postures, particularly crossed-leg and heel sitting postures, are popular among Thai people for these types of activities (see Figure 1). Workers often assume such postures for prolonged periods, which is likely to be one risk factor for low back pain (LBP) (Solomonow *et al*. 2003, Keawduangdee *et al*. 2011).

Prolonged non-neutral static postures, such as seated postures, can increase the fatigability of the lumbo-pelvic muscles, particularly the lumbar multifidus (LM) and internal oblique (IO) muscles (Harrison *et al*. 1999). These muscles represent a local system for counterbalancing compressive forces on the upper lumbar segment of the spine and to increase lumbar stability (Kavcic *et al*. 2004) throughout the sitting period. Sustained contraction of these back muscles in seated postures has been identified as a cause of increased back muscle fatigue (van Dieën *et al*. 1997) and may eventually lead to development of LBP (Frymoyer *et al*. 1980, Wilder *et al*. 1988). Although previous research has reported findings on the effect of seated postures on back muscle activity and fatigue (Nag *et al*. 1986), to date no study has evaluated LM and IO muscle fatigue in floor sitting postures, particularly in crossed-leg and heel sitting postures in Thai cottage industry workers. The correlation of measures of muscle fatigue and discomfort has also not been assessed in this work context.

Surface electromyography (sEMG) is a non-invasive muscle activity measurement method that can also be used to objectively assess muscle fatigue (De Luca 1993, Dedering *et al*. 1999, 2002) and fatigue rates. Fatigue during sustained contractions is characterised by a shift in the power spectrum of the EMG signal or spectral

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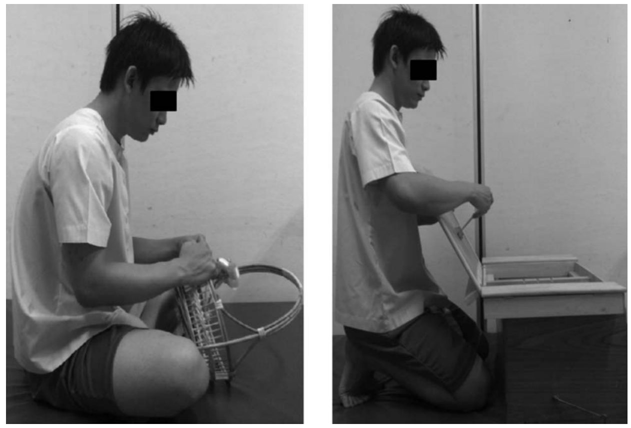

Figure 1. Images of Thai handicraft work being performed in typical crossed-leg and heel sitting postures.

compression (Ng *et al*. 1997). The median frequency (MF) value is the most commonly used outcome measurement of sEMG for assessing muscle fatigue (De Luca 1997, Mannion *et al*. 1997, Roy *et al*. 1997, Sparto *et al*. 1997). A decrease in the MF of the EMG power spectrum or a decrease in its slope during an isometric contraction is an indicator of myoelectric muscle fatigue (Biedermann *et al*. 1991, De Luca 1997). In general, the slope of the MF reflects muscle fatigue and has been widely used to predict and investigate back muscle fatigue (Biedermann *et al*. 1991).

Many subjective measurement techniques have been developed in the literature for assessing body discomfort, including Borg ratings (Dedering *et al*. 1999, 2002, Yassierli and Nussbaum 2007) and the visual analogue scale (VAS) ratings (Lyons *et al*. 1993, Kumar 2006). The VAS is a general instrument that can be customised to applications in terms of scale configuration. For example, VAS scales have been used to measure trunk discomfort (Kumar 2006). VAS ratings of postural comfort are inexpensive, efficient and practical for almost any field setting. Lyons *et al*. (1993) also demonstrated the use of VAS ratings to measure fatigue of masseter and temporalis muscles. They found a significant relationship between VAS ratings and MF shift of EMG. However, no previous research has studied handicraft floor sitting postures using sEMG measures of lower trunk muscle fatigue and VAS ratings of discomfort.

Therefore the purpose of this study was to: (1) assess trunk muscle fatigue in seated handicraft tasks using sEMG analysis along with lower trunk discomfort using VAS ratings and (2) identify any relationship between VAS ratings and sEMG measures as indicators of muscle fatigue.

2. Methods

2.1. Participants

Twenty-three healthy Thai male participants were recruited for the study from the general population of the Khon Kaen City area. We elected to study male subjects, in part, based on the demographics of the Thai cottage industry working population and to provide some initial insight into the role of common work postures in muscle activity and back pain. Participants had a mean age of 21.6 years (SD = $\pm$2.55, range = 20–30), mean height of 168.57 cm (SD = $\pm$ 4.57, range = 161–180), and mean weight of 58.16 kg (SD = $\pm$ 5.38, range = 50–68). All participants reported daily work activities involving the crossed-leg and heel sitting postures (on a floor) for at least 30 min. Furthermore, all participants reported experience in these postures for at least eight years. We ensured through an initial survey that participants had similar levels of experience with the test postures through their work activities.

None of the participants reported LBP in advance of testing nor did they have documented spinal disorders (e.g. scoliosis, spondylolisthesis, lumbar herniated nucleus palposus, ankylosing spondylitis), neurological conditions (numbness or loss of sensation in the trunk and/or legs before testing), recent lumbo-pelvic and/or abdominal surgery, or abnormal muscle contractions. The participants also did not exhibit pain symptoms during rest or test periods (including back pain, leg pain or numbness at the back or their legs). All participants signed an informed consent form to participate in the study. The study was approved by the Ethics Committee for Human Research at Khon Kaen University.

2.2. Experiment design

2.2.1. Variables

The independent variable for this study was the type of sitting posture, including: crossed-leg and heel sitting postures. These postures were observed in visits to domestic and cottage workshops producing handicrafts in the Khon Kaen area. The postures were assumed by the vast majority of workers and for extended periods of time of 30 min or greater. The dependent variables included normalised MF slope using sEMG for measuring lower trunk muscle fatigue in the sitting postures and lower trunk discomfort ratings using a VAS presented to participants at the end of sitting periods. A within-subjects design was followed in which all participants were exposed to the two posture positions. The order of the exposure was randomised across participants.

2.2.2. Procedures

The study was conducted in the Associated Medical Sciences Laboratory at Khon Kaen University. Although the intent was to demonstrate the impact of actual industry work task postures on muscle fatigue and discomfort, a controlled lab investigation was initially conducted to isolate posture position effects on the responses as well as any relation among the sEMG measures and VAS ratings. This study was expected to motivate a follow-on field investigation. For each participant, the experiment was administered across two consecutive days with a 24-hr break between sessions. The equivalent of a one-day 'wash-out period' was used between postures according to the methodology described by Jones *et al.* (2004).

Participants were initially provided with a familiarisation session outlining the two sitting postures. They were also shown pictures of the postures, as typically assumed by workers in Thai cottage industry during daily work tasks. Participants practiced the sitting postures until they could readily assume and maintain the task position. Subsequently, a researcher asked the participants to rest in a supine lying position for 10 min (Jones *et al.* 2004). Participants then sat unsupported on a cushion for 30 min in the crossed-leg or heel sitting posture depending upon their random sequence assignment. During the sitting period, a small vertical stand was placed behind participants and they were instructed by a researcher to adjust their posture position in order to maintain point of contact between the stand and the L3 spinous process level on the back. Participants did not lean or apply any significant pressure to the stand. In addition, all participants were instructed to look at a designated point 1.5 m in front of them at seated eye level.

To perform the crossed-leg sitting posture, participants were asked to sit with their thorax relaxed. Both hips and knees were flexed with the calf of each leg placed on the top of the opposite foot with the lower leg resting on the cushion (see Figure 2a; posture referenced from [Thailand] Office of the National Culture Commission 2009). To perform the heel sitting posture, participants were asked to sit with their thorax relaxed. Both hips and knees were fully flexed and contacted the seat cushion, and both feet were in dorsiflexion with ischial tuberosities resting on the heels (see Figure 2b; posture referenced from Office of the National Culture Commission 2009). Each sitting posture was performed for 30 min on separate days.

2.2.3. Data collection

The skin over the boundaries of both sides of the LM and IO muscles was prepared by shaving hair at electrode sites, cleaning sites with alcohol and abrading skin using fine sandpaper in order to reduce skin impedance to less than 5 kΩ (Hermens *et al.* 2000). Two pairs of active adhesive disposable Ag/AgCl disc surface electrodes (EL 503, BIOPAC Systems, California) were then placed parallel to the both sides of the muscles (O'Sullivan *et al.* 2006). For the LM muscle, this was a location at the level of the L5 vertebrae, parallel to an imaginary line between the posterior superior iliac spine and the L1–L2 interspinous space (De Foa *et al.* 1989). For the IO muscle, this was a location 1 cm from the anterior superior iliac spine towards the median plane (De Luca 1993). The centre-to-centre distance of electrodes was 2.5 cm. Two ground electrodes were placed on both anterior superior iliac spines and iliac crests. Snap leads were connected between surface electrodes and amplifiers to transfer signals, and all electrodes were taped to avoid lead movement.

A Biopac MP 35 sEMG system (Goleta, California) was used to continuously record EMG signals during the sitting periods. The sampling rate was 1000 Hz with a signal amplification of gain $\times$ 1000 and a common mode rejection ratio (CMRR) of 85 dB. A bandpass filter was applied to the data with lower and upper cutoff frequencies of 30 Hz and 500 Hz, respectively. A personal computer with an A/D converter was used to analyse the EMG data. A Fast Fourier Transform (FFT) was applied with 1-s data epochs (including 1000 data points) and used to

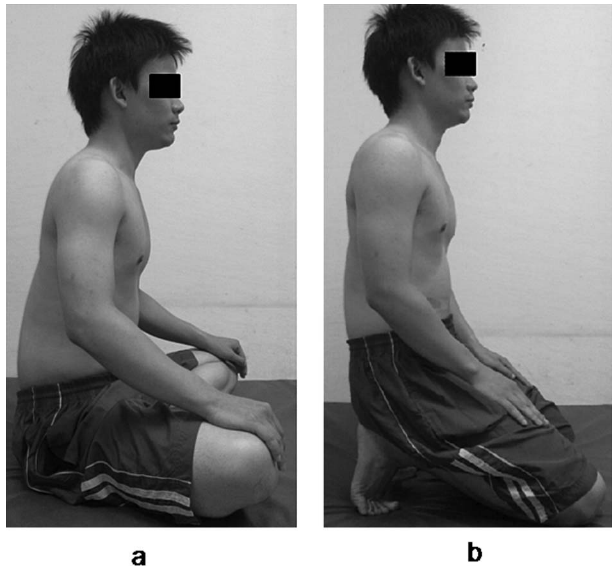

Figure 2. (a) Crossed-leg sitting posture. (b) Heel sitting posture.

calculate the signal spectrum (Stulen and De Luca 1981). All test trial MF data were normalised based on participant initial MF values at rest. Linear regression analysis was applied to the normalised MF observations (1800) during each 30-min sitting period in order to determine the normalised MF slope (NMF slope). The NMF slope was defined as the MF slope divided by the initial MF value and expressed in per cent per second.

In order to assess lower trunk discomfort, a VAS was presented to participants at the end of each 30-min sitting period. The scale was based on Kumar's (2006) research and was a 10 cm horizontal line with anchors at the two ends reading 'no discomfort at all' and 'worst imaginable discomfort'. The ratings were also used to identify any correlation of lower trunk discomfort with sEMG measures of trunk muscle fatigue.

2.2.4. *Hypotheses*

Kiefer *et al.* (1998) claimed that muscle activation in a neutral sitting posture, under upper body load, involves a subtle but distinct local muscle recruitment pattern, especially for the LM and IO muscles, in order to maintain an equilibrium posture. On this basis and Harrison *et al.* (1999) findings, it was expected that prolonged exposure to the crossed-leg and heel sitting postures would lead to fatigue of the trunk muscles, specifically the LM and IO muscles (Hypothesis (H) 1). Since heel sitting represented a near-neutral sitting posture, it was hypothesised to produce less fatigue in the lower trunk muscles and discomfort when compared with the crossed-leg sitting posture (H2).

It was further expected that the EMG measures of LM and IO muscle fatigue in the floor sitting postures would be related to the VAS discomfort ratings. Normalised MF slope was expected to be negatively correlated with VAS ratings; that is, as lower trunk muscle fatigue increased (and the NMF slope decreased), lower trunk discomfort ratings were expected to increase over the period of sitting (H3). This expectation was based on prior observation of a dependence among objective and subjective measures of muscle fatigue and discomfort, respectively (Dedering *et al.* 1999, Vergara and Page 2002) as well as Lyons *et al.* (1993) findings that VAS ratings were an indicator of masticatory muscle fatigue.

2.2.5. *Statistical analysis*

SPSS version 19.0 for Windows (Chicago, IL) was used for all statistical analyses. Diagnostics were initially performed on the NMF slope response determined for both sides of the LM and IO muscles for each participant in each sitting posture for the 30 min test period. Shapiro–Wilk's test results revealed the MF data to conform with the normality assumption for parametric statistical tests. Levine's test confirmed conformance of the MF data with the parametric test assumption of constant variance. The data were subsequently analysed using a two-way analysis of variance (ANOVA) with sitting posture and muscle as the independent variables. When a significant sitting posture $\times$ muscle interaction effect was detected, pair-wise comparisons were used to examine differences between the postures for each muscle.

Lower trunk muscle discomfort, measured by VAS ratings, was compared between the crossed-leg and heel sitting postures with independent *t*-test.

For the correlation analyses on the two response measures, Pearson product–moment correlation coefficients (r) were determined to quantify the degree of linear association between the NMF slope for the right LM and IO muscles and the VAS ratings in the crossed-leg and heel sitting postures. We assumed equal fatigue rates for both sides of the muscles in symmetrical sitting postures. An alpha level of 0.05 was defined as representing statistical significance. Interpretation of the correlation coefficients was as follows: 0.0–0.25 – little correlation; 0.26–0.49 – low correlation; 0.50–0.69 – moderate correlation; 0.70–0.89 – high correlation and 0.90–1.00 – very high correlation.

3. Results

A two-way ANOVA was applied to the mean magnitude of the NMF slope response. Results revealed a statistically significant sitting posture × muscle interaction effect on the slope ($F(3,176) = 2.949$, $p = 0.034$) (see Table 1 and Figure 3). Pair-wise comparisons revealed the crossed-leg sitting posture to produce a significantly steeper NMF slope (more negative) for both sides of LM and IO muscles than the heel sitting posture ($p < 0.001$). The mean differences in NMF slope between the two sitting postures were: -0.062 ± 0.025%/s for right LM muscle (with 95% confidence interval, CI − 0.072 to − 0.053); -0.064 ± 0.018%/s for left LM muscle (with 95% CI − 0.073 to − 0.055); -0.077 ± 0.021%/s for right IO muscle (with the 95%CI − 0.086 to − 0.068); and -0.077 ± 0.019%/s for left IO muscle (with the 95% CI − 0.086 to − 0.068).

A *t*-test revealed significantly greater discomfort in the lower trunk ($t(44) = 3.722$, $p = 0.001$), measured with the VAS, for the crossed-leg sitting posture than for the heel sitting posture. The mean difference between the postures was 2.01 ± 1.86 cm, 95%CI 0.92 to 3.09; $p = 0.001$) (see Figure 4).

Table 1. Two-way analysis of variance (ANOVA) testing the effects of sitting posture and muscle on mean magnitude of normalised median frequency slope (n = 23).

Effect	df	*F*-value	*p*-value
Posture	1	909.929	<0.001*
Muscle	3	10.701	<0.001*
Posture × muscle	3	2.949	<0.034*

Note: n = group size; *statistically significant ($p < 0.05$).

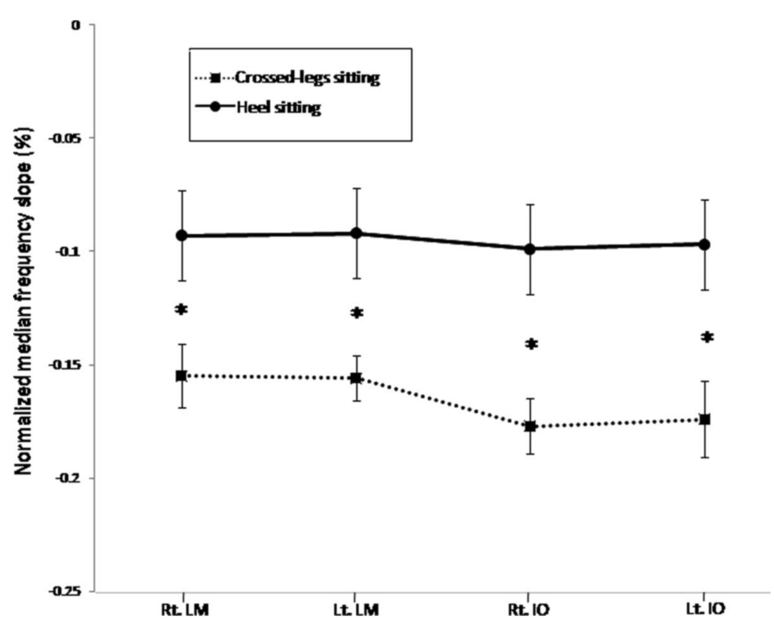

Figure 3. Means and standard deviation (SD) of NMF slope (%) for right lumbar multifidus (Rt. LM), left lumbar multifidus (Lt. LM), right internal oblique (Rt. IO) and left internal oblique (Lt. IO) for the crossed-leg sitting posture (dash line) and heel sitting posture (solid line) ($n = 23$) (*$p < 0.001$).

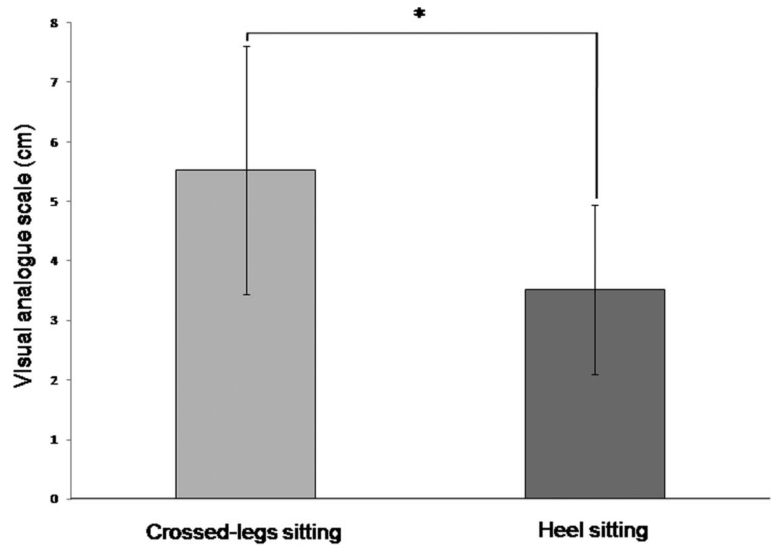

Figure 4. Means and standard deviation (SD) of VAS (cm) at 30 min for the crossed-leg and heel sitting postures ($n = 23$) (*$p = 0.001$).

The correlation analyses yielded coefficients demonstrating highly significant negative linear associations between the NMF slope and the VAS ratings of discomfort for the right LM and IO muscles in the crossed-leg sitting posture ($r = -0.85$ for right LM muscle; $p < 0.001$, and $r = -0.86$ for right IO muscle; $p < 0.001$).

Similarly, Pearson product–moment coefficients revealed highly significant negative correlations among the EMG response and the VAS ratings in the heel sitting posture ($r = -0.84$ for right LM muscle; $p < 0.001$, and $r = -0.85$ for right IO muscle; $p < 0.001$). The correlation analysis results are also presented in Figure 5. The results for the left LM and IO muscles were similar to those shown for the right side.

4. Discussion

The purpose of this study was to assess trunk muscle fatigue in seated handicraft tasks using sEMG analysis and VAS ratings for lower trunk discomfort, and to identify any relation of sEMG and VAS ratings for indicating trunk muscle fatigue in cottage industry work tasks. In general, we found that the crossed-leg and heel sitting postures were fatiguing to the LM and IO muscles. This finding supported H1. Results also indicated that fatigue and VAS ratings for lower trunk discomfort were greater for the crossed-leg versus heel sitting posture for the 30-min sitting period. These results supported H2. In addition, muscle fatigue was significantly correlated with VAS ratings, specifically decreases in NMF slope occurred with increases in discomfort ratings during both crossed-leg and heel sitting. This finding supported H3. On the basis of these results, it can be inferred that trunk muscle fatigue led to the development of perceptions of discomfort for participants in the seated postures. Furthermore, it appears that the heel sitting posture is more resistant to lower trunk muscle fatigue and lower trunk discomfort than the crossed-leg sitting posture. In addition, the objective and subjective assessments of muscle fatigue are largely concordant for the specific task postures examined in this study. Below we provide some explanations for these findings.

Although the crossed-leg and heel sitting postures are both symmetrical floor sitting postures, when observing participants during the two data collection sessions, the lumbo-pelvic posture position was found to be different. The difference in postures may have resulted from different centres of gravity which result from different positioning of the trunk. Consequently, the two postures require different levels of LM and IO muscle activities to maintain position. Trunk position in different unsupported sitting postures could preferentially facilitate distinct LM and IO activations (O'Sullivan *et al.* 2006). Furthermore, it has been reported that the activation of low back muscles, especially the LM muscle, can be highly related to fatigue (van Dieën *et al.* 1993). Thus, it is likely that the biomechanical difference of the trunk position affected trunk muscle fatigue at different levels (Champagne *et al.* 2008).

There are two possible explanations for the finding that crossed-leg sitting produced greater LM and IO muscle fatigue and discomfort ratings for the lower trunk than the heel sitting posture. First, the crossed-leg sitting posture may have a mechanical disadvantage compared to the heel sitting posture. In the crossed-leg sitting posture, the hip

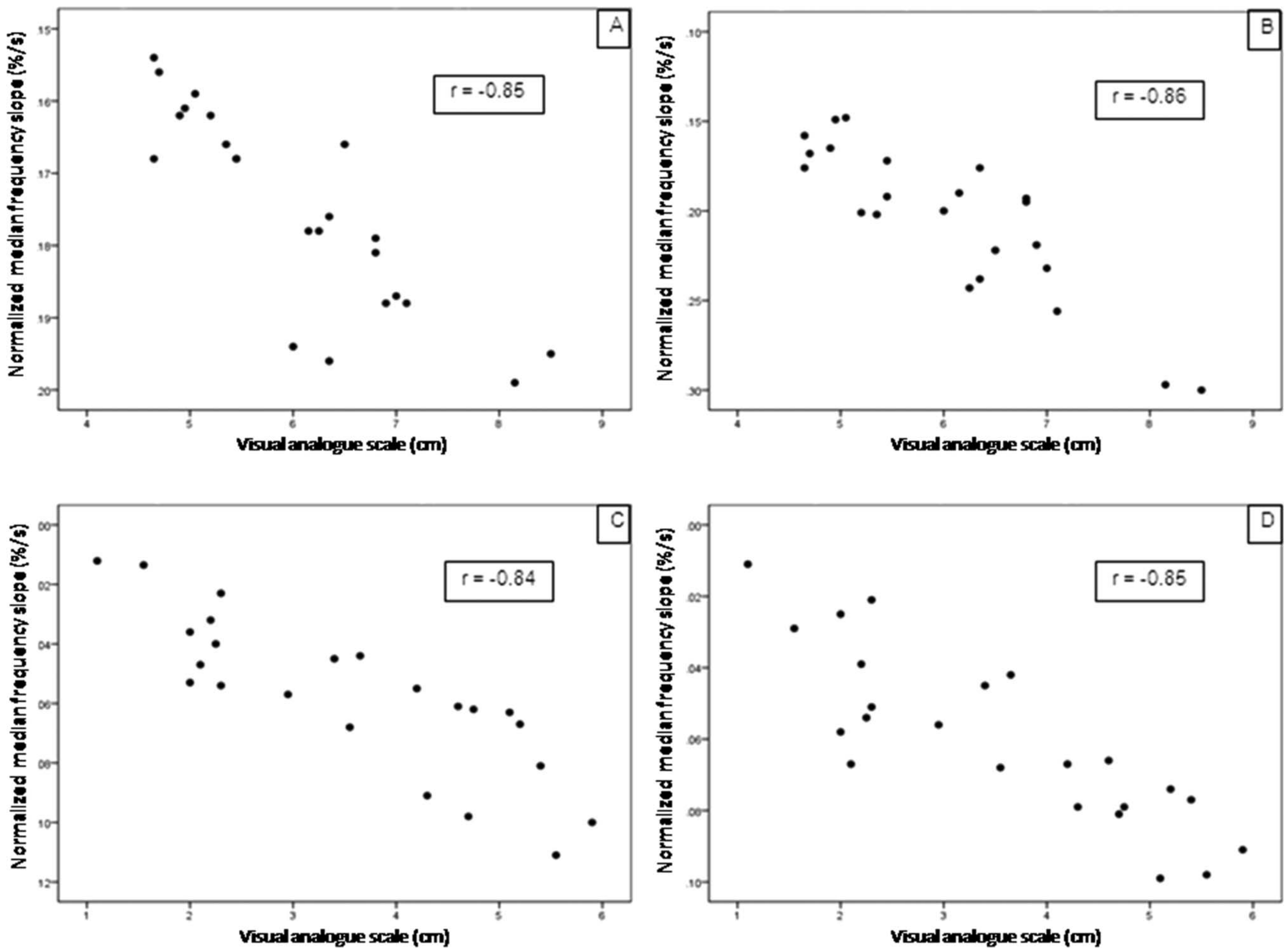

Figure 5. Correlation between the NMF slope and VAS of right lumbar multifidus muscle (A) and right internal oblique muscle (B) in the crossed-leg sitting posture, and right lumbar multifidus muscle (C) and right internal oblique muscle (D) in heel sitting posture ($n = 23$).

joint was at approximately 90 degrees of flexion and almost fully externally rotated. This particular position of the joint may cause the sitter to lean their trunk forward due to decreased thigh-trunk angle (Harrison *et al*. 1999). This trunk posture, with the line of thrust from the centre of gravity passing in front of the spine and ischial tuberosities, would cause greater LM and IO muscle activity, and more rapidly lead to fatigue due to an increasing flexor moment arm at the lumbar spine (see Figure 6). Although Nag *et al*. (1986) observed that back muscle activity was reduced in a crossed-leg sitting posture, they measured erector spinae muscle activity, which is located at a superficial level in the back and only acts as a prime mover in posture positioning. In contrast, the LM muscle acts as a synergist (stabilisation) muscle in the crossed-leg sitting posture (Bergmark 1989). Thus, the LM muscle may increase in activity in order to maintain the stability of the sitting posture. Second, the LM muscle may be passively stretched by inclination of the forward trunk as effected in the crossed-leg sitting posture. The muscle then increases in tension to pull on the lumbar spine and resists the increase of the flexor moment arm. This tension maintains equilibrium of the sitting posture and prevents the individual from falling forward (Corlett 2008). The tension generation of the muscle may contribute to a greater sensation of discomfort in the lower trunk by stimulating mechanoreceptors located in muscles and tendons (Keyserling *et al*. 2005). While the LM is being passively stretched, the IO muscle may respond by increasing its co-contraction activity to balance forces with the other back muscles; ultimately, this would induce greater IO muscle fatigue in the crossed-leg sitting posture.

With greater trunk erection in the heel sitting posture, the LM and IO muscles are comparatively less active than in crossed-leg sitting, since the centre of gravity passes posteriorly and nearer to the fulcrum of the lumbar spine. Thus, the heel sitting posture can be described as a near-neutral sitting posture. In addition, the heel sitting posture may produce a lower flexor moment arm for the upper body (see Figure 7). Kiefer *et al*. (1998) claimed that muscle activation in the neutral sitting posture, under upper body load, may cause a subtle but distinct recruitment pattern among local muscles, especially the LM and IO, in order to maintain an equilibrium posture. We also observed that the lordotic curve of the lumbar spine in heel sitting more closely approximated the curve of the spine when standing. The LM muscle in heel sitting may also be less passively stretched as compared to crossed-leg sitting; therefore, the heel sitting posture showed less LM and IO fatigue. Related to this, VAS ratings for the heel sitting posture were lower than for crossed-leg sitting, corresponding with lower LM and IO muscle fatigue.

Results clearly revealed that NMF slopes for the right LM and IO muscles decreased as VAS ratings increased (representing higher trunk discomfort). This may be due, in part, to the susceptibility of the trunk muscles to

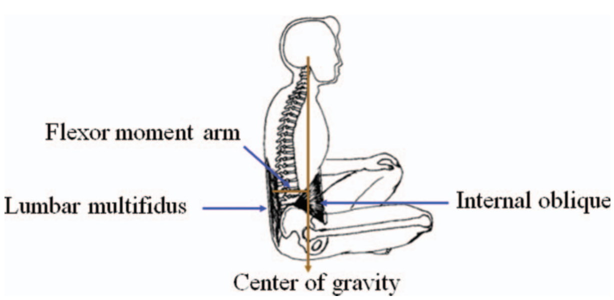

Figure 6. Flexor moment arm of lumbar multifidus muscle and centre of gravity of the participant while in the crossed-leg sitting posture.

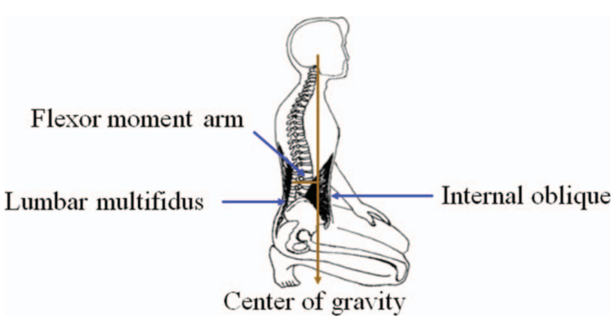

Figure 7. Flexor moment arm of lumbar multifidus muscle and centre of gravity of the participant while in the heel sitting posture.

fatigue, leading to increased segmental instability (Hansen *et al.* 1998) and discomfort. Sustained static muscle contraction without trunk movement in such postures may induce metabolite accumulation in the trunk muscles and lead to fatigue development (Pope *et al.* 2002). Related to this, previous research proposed that prolonged sitting positions may cause trunk muscle fatigue (Frymoyer *et al.* 1980, Wilder *et al.* 1988). Among other actions, the LM and IO muscles provide lumbo-pelvic stability and directly control lumbar spinal segments (O'Sullivan *et al.* 2006). Fatigue of these muscles may lead to decreased stability of the lumbar spine (Todd *et al.* 2007). Such segmental instability may cause overloading of vertebral structures (Hansen *et al.* 1998, Pope *et al.* 2002). Overloading of the vertebral structures and development of lower trunk muscle fatigue during prolonged sustained contraction may provoke the observed discomfort in the lower trunk of sitters (Hansen *et al.* 1998, Allen *et al.* 2008). Although, one prior study did find a significant correlation between MF and VAS ratings (Lyons *et al.* 1993), results were based on masseter and temporalis muscle responses. This study focused on trunk MF and discomfort in common industry work postures.

Previous research has indicated that participants may over- or under-estimate feelings of 'lower trunk discomfort' versus 'pain' when using the VAS ratings (Callaghan *et al.* 2010). However, other research indicates this finding may be dependent on participant experience with the measurement methodology (Dedering *et al.* 2002). For this reason, all participants in this study were familiarised and had practice with the VAS ratings before data collection. Subjective ratings using VASs may also depend on participant prior experiences of physical tasks and coping strategies. Participants in this study were all consistently trained in the two sitting postures before data collection. Consequently, all participants had sufficient experience with the specific VAS to make accurate ratings of postural discomfort based on their feelings. Related to this, the VAS ratings of discomfort by experienced participants could be used to describe seat comfort and as a basis for design.

The findings of this study suggest that a heel sitting posture is superior to a crossed-leg posture in terms of trunk muscle fatigue and discomfort, when workers need to perform floor activities. This finding is not limited in applicability to handicraft workers in Thailand, as such postures are adopted in a variety of occupational and domestic settings in many countries throughout Asia and Africa. For example, similar and extended crossed-leg postures are assumed by workers in African countries and India involved in clay pottery making tasks in which the product is held between the legs or adjacent to the legs.

There are some limitations of this study that should be noted relative to application of the results. First, the heel sitting posture investigated here may not be a possible position for people to maintain, if they have knee and/or ankle pain. This posture is likely to produce more compressive force on the knees and ankles and would not be comfortable or healthy for such individuals. Second, it is important to note that we only investigated fatigue in the LM and IO muscles in very specific sitting postures, including crossed-leg and heel sitting. Therefore, this study does not reflect fatigue in other areas of the body in different posture positions. Third, ischemic effects and pain or numbness in the legs during sitting might have influenced LM and IO muscle fatigue and perceptions of discomfort, confounding participant VAS ratings. For this reason, advance screening of participant condition was conducted; however, it is possible that some persons had prior conditions. Fourth, this study included only male participants. Although the observed demographics of workers in the Thai cottage industry (Teeratrakul *et al.* 2009) include a slight majority of males, females account for approximately 45% of the current working population. Consequently, additional data is needed on the female segment of the handicraft worker population for making further inferences about muscle activity level and pain. Finally, this study was conducted in a laboratory setting. Future studies should include female participants and be conducted in field settings in order to promote the validity of results.

5. Conclusion

The findings of this study revealed that floor sitting postures in handicraft work can be fatiguing to lower trunk muscles and cause low back discomfort over time. Among common postures observed in Thai handicraft industries, heel sitting may be a preferred posture choice when performing work tasks on a floor. The heel sitting posture causes less fatigue in lower trunk muscles and discomfort than a common crossed-leg sitting posture in a healthy person without pre-existing knee and ankle pain. It is also superior in terms of these responses during prolonged floor activity (30 min). In addition, findings reveal that VAS discomfort ratings are a complementary indicator of lower trunk muscle fatigue levels to sEMG for cottage industry work tasks.

Future studies should be conducted on fatigue and discomfort measurement in both trunk and leg muscles in other floor sitting postures. Finally, this study did not address the issue of whether lower trunk discomfort in participants is influenced by central or peripheral fatigue mechanisms or both. Therefore, it would be worthwhile for future studies to discriminate causes of lower trunk discomfort when maintaining crossed-leg and heel sitting postures, as well as other postures.

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