Postural effect on muscular activities of Electronics workers in Malaysia

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Abstract

Introduction: Working posture has been identified as one of the major risk factors associated with work related musculoskeletal disorders (WMSD). Working posture has been reported to affect performance (Drury \textit{et al}. 2008), and both standing and sitting postures have been reported to be associated with MSDs and other health problems (Messing \textit{et al}. 2008). These MSDs occur in different body regions and the major body regions identified with high prevalence rate include the neck, shoulder, back, wrist or legs. The level of prevalence or intensity at the regions however differs by task, profession/occupation and other physical or psychosocial factors (Andersen \textit{et al}. 2007). This study compares muscular activities among 11 asymptomatic standing and sitting electronic workers, in order to identify any significant difference in the level of WMSD among them.

Method: Eleven assembly workers made up of six males and five females from two electronics assembly plants in Johor Bahru Malaysia took part in the study. They are made of five workers who carried out their job activities sitting, and another six workers, whose tasks required that they stand while working. In other to reduced accumulated effect on the muscles, measurements were only initiated at the participants’ resumption of duty or after break. Surface electromyography, using bipolar electrodes, was used to evaluate muscular activities in both sides of the neck, upper back, lower back, and both hands and legs for one hour. The electrical signals were analysed for change in mean power frequency (MPF) and average integrated EMG (AEMG). The EMG signals were band passed filtered at 20-450Hz with a sampling frequency of 1000Hz. All the MPF and AEMG values for each participant were exported to SPSS version 18. The signals were plotted at 10 minutes interval to identify any significant trends. A non-parametric test (Mann-Whitney Test) was carried out on the data to determine whether there are significant differences in the workers’ postures.

Results: Only in both hands and the left neck did both the MPF and AEMG reveal significant difference in muscular activities of standing and sitting workers. Also, no significant difference in both MPF and AEMG was observed in the left leg of the workers. In other muscles, AEMG reveals significant difference in EMG activities between standing and sitting workers, while the MPF does not reveal any difference. However, the reduction in frequency was not significant enough to show fatigue among both standing and sitting workers.

Discussion: In this study, sitting workers revealed higher level of muscular activities in the upper body regions of the neck and the upper back, while there were higher activities among standing workers in the lower body region of the lower back and the leg. Generally, male standing workers also maintained stable muscular activities than women as women are more susceptible to fatigue than men (Trestear and Burr 2004, Messing \textit{et al}. 2008). However, the value of the change in EMG frequency in this study did not identify significant fatigue. This lack of significant evidence of fatigue may be due to the 1 hour test duration which may be too short for significant fatigue to occur (Durkin \textit{et al}. 2006). This period might still be sufficient for effective posture adjustment, due to the workers ability to identify regions of discomfort, thereby altering posture for comfort (Ohashi \textit{et al}. 2008). Hence, organisations making provision for short breaks after every hour might reduce WMSD, and improve general wellbeing of the workers.

Practitioner Summary: the study investigated the occurrence of muscular fatigue among standing and sitting factory workers and discovered that there was no significant fatigue in both standing and sitting workers after working for one hour. It therefore recommends introduction of short breaks after every hour to minimise workers fatigue, which has been responsible for loss of individuals and organisational productivity.
Keywords: Musculoskeletal disorder, fatigue, electromyography, posture.

1. Introduction

Musculoskeletal disorders (MSDs) remain a major occupational problem affecting the general well-being of working adults all over the world (Lanfranchi and Duveau 2008). It accounts for major cost for insurance and health cost associated with national productivity (Guo et al. 1999). These MSDs occur in different body regions and the major body regions identified with high prevalence rate include the neck, shoulder, back, wrist or legs. The level of prevalence or intensity at the regions however differs by task, profession/occupation and other physical or psychosocial factors (Andersen et al. 2007). This high prevalence of MSD in different body regions with little evidence of successful intervention must be responsible for previous conclusion about its ubiquitous nature (Andersen et al. 2007). Some studies has identified back pain as the most severe and one of the most costly, because its account for one-third of all cost of compensation (Daynard et al. 2001, Marshall et al. 2011, Schinkel-Ivy et al. 2013). This may be because the back region shows major link between the various risk factors and MSD (Lanfranchi and Duveau 2008).

One of the major risk factor associated with the problem is the working posture of workers. The major work postures have been standing and sitting. Working posture has been reported to affect performance (Drury et al. 2008), and both postures have been reported to be associated with MSDs and other health problems (Messing et al. 2008). Studies have recommended alternating the two postures since the most effective portion of the two working postures remained unknown (Messing et al. 2008). While variation in work posture is beneficial (Vink et al. 2009), this might be challenging in some tasks such as assembly and packaging. While superiors and supervisors are at liberty to alter their working postures as they move about inspecting and monitoring tasks, the same cannot be said of some of the assembly or factory workers who are restricted to particular workstations for extended working hours carrying out repetitive tasks. These workers are expected to adapt a particular working posture based on the task they are performing. This static work postures which reflects poor workplace design has been reported to be responsible for musculoskeletal disorders (MSDs) in the upper body parts (Lin and Chan 2007). In developing countries such as Malaysia, which is a hub for manufacturing companies, these postures were pre-determined by the manufacturers’ primary practises in their host countries. These postures were determined without cognisance to the anthropometric and other physical differences between the host countries and the parent country of the manufacturing organisation. These lack of recognition for anthropometric and physical difference has been identified as a potential risk factors for ergonomics problems such as MSD among workers (Lin and Chan 2007).

Also, previous studies have reported evidence of fatigue among workers who work for two hours or more. For example, low back pain was reported among sitting workers who work for two hours (Mörl and Bradl 2013). Low back pain was also reported among standing workers who work continuously for two hours (Gregory and Callaghan 2008). People working on computers for 4 to 6 hours or more were also reported to have higher chances of reporting MSD than those who work for lesser period (Joling et al. 2008), and for those who focused on the video display terminal for 7 or more hours (Lin and Chan 2007). Farmers who worked for 2 more hours than other farm workers also reported more MSDs in different body regions (Kolstrup 2012). There are no reported investigations of fatigue within an hour of working among workers. This study is therefore aimed at evaluating the effect of working postures on the workers’ muscles while working for an hour, in order to determine the level of fatigue among them.

2. Methods

2.1 Participants

Eleven assembly workers made up of six males and five females from two electronics assembly plants in Johor Bahru Malaysia took part in the study. They are made of five workers who carried out their job activities sitting, and another six workers, whose tasks required that they stand while working. Only workers that gave their consent and have not taken medical leave or show any reaction during the study were included in the final analysis. The participants’ age vary between 20 and 35 years. The protocols were
approved by the Research committee of the Faculty of Mechanical Engineering of the Universiti Teknologi Malaysia and National Institute of Occupational Safety and Health, Malaysia.

2.2 Procedure

The workers were invited to a private room where they were assured of the safety of the exercise and informed of the purpose of the study. Only workers who gave their consent were included in the study. In order to reduce accumulated effect on the muscles, measurements were only initiated after the participants’ resumption of duty or after break. The targeted parts of the participants’ skin were shaved and cleaned with methylated spirit to minimise skin impedance. The disposable electrodes were thereafter fixed to the targeted muscles before connecting to the electromyography device. The participants thereafter returned to their duty post and the EMG device monitored the muscular activities continuously for one hour without interruption. However, the researchers could not observe the job sequence to identify their intensity because they were not directly allowed into the factory due to the companies’ privacy policy. The workers returned to the room after the set time of one hour and have the electrode disconnected.

2.3 Instrumentation and data processing

Five muscles were monitored bilaterally on each of the participants while carrying out their duties. They are the upper trapezius muscles around the C5-C7 vertebrae in the neck region, the middle fibres of the trapezius muscles at the thoracic area of the upper back, the erector spinae muscles at the L4-L5 lumbar vertebra area of the lower back, the gastrocnemius muscles on both legs and the extensor carpi radialis longus muscles on both hands. Disposable electrodes (Ambu Blue Sensor) were connected to the targeted muscles at an inter electrode distance (IED) of 25mm. The bipolar electrodes were connected parallel to the direction of the muscle fibres while the earth electrode were connected 20-30mm away from the bipolar electrodes. The electrodes were all connected to a 16 channelled Megawin ME6000 surface electromyography device.

The data were processed using MEGAWIN 3.0 windows software. The EMG signals were band passed filtered at 20-450Hz with a sampling frequency of 1000Hz. The fatigue which is an indication of the change in Mean Power Frequency (MPF) and Average integrated EMG (AEMG) were analysed using the software. The MPF is the weighted average frequency, and the AEMG is the resultant average EMG obtained from every Fast Fourier Transform (FFT) frame. The values were normalised with the Maximum Voluntary Contraction of each muscles expressed in Hz for the MPF and µV for AEMG.

2.4 Statistical Analysis

All the MPF and AEMG values for each participant were exported to SPSS version 18. The signals were plotted at 10 minutes interval to identify any significant trends. A non-parametric test (Mann-Whitney Test) was carried out on the data to determine whether there are significant differences in the workers’ postures and their gender. All tests were conducted at the 0.05 significant levels.

3. Results

Figure 1 shows the rate of fatigue based on working posture. No significant difference was observed between the left and right side muscles except in the AEMG of the lower back and the leg. The AEMG graphs of the lower back also revealed similarity in the left muscles of standing and sitting males with the activities showing no sign of fatigue. The same behaviour can be observed in the muscles of their right leg. The graphs revealed observable differences in the male and female trends in most of the muscles observed, with female workers recording higher activities in most of the muscles observed. The muscles of the female workers demonstrated diverse trend when compared with their male counterparts, which showed lower slope as the working time increases.

In the neck region, decrease in frequency, an indication of setting in of fatigue, was observed in standing workers; after 50 minutes in men and 30 minutes in women. However, there is evidence of higher level of muscular activities in sitting workers, with evidence of the
Figure 1: The Average electromyography (AEMG) and mean power frequency (MPF) to investigate muscular fatigue in different body regions.

setting in of fatigue only visible in the left neck of women. At the upper back region, decrease in frequency can only be observed among sitting men. However, at the lower back, the MPF revealed gradual decrease in the EMG frequencies in both standing and sitting workers, although the activities were more stable in men
than women. Reduction in MPF can be observed after 30 minutes in legs of both standing and sitting workers while the workers did not show any sign of fatigue in the hands.

Table 1 shows regions where there is significant difference between muscles of standing and sitting workers. Only in both hands and the left neck did both the MPF and AEMG reveal significant difference in muscular activities of standing and sitting workers. Also, no significant difference in both MPF and AEMG was observed in the left leg of the workers. In other muscles, AEMG reveals significant difference in EMG activities between standing and sitting workers, while the MPF does not reveal any difference.

Table 1: Mann-Whitney (non-parametric) test of difference in fatigue between standing and sitting workers.

<table>
<thead>
<tr>
<th>Body region</th>
<th>Side</th>
<th>Mean rank sitting</th>
<th>Mean rank standing</th>
<th>p-value</th>
</tr>
</thead>
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<tr>
<td>Left Neck</td>
<td>MPF</td>
<td>39.52</td>
<td>28.49</td>
<td>0.018</td>
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<tr>
<td></td>
<td>AEMG</td>
<td>41.83</td>
<td>26.56</td>
<td>0.001</td>
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<tr>
<td>Right Neck</td>
<td>MPF</td>
<td>32.25</td>
<td>34.54</td>
<td>0.627</td>
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<tr>
<td></td>
<td>AEMG</td>
<td>44.18</td>
<td>24.6</td>
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</tr>
<tr>
<td>Left upper back</td>
<td>MPF</td>
<td>32.05</td>
<td>34.71</td>
<td>0.571</td>
</tr>
<tr>
<td></td>
<td>AEMG</td>
<td>40.08</td>
<td>28.01</td>
<td>0.011</td>
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<tr>
<td>Right upper back</td>
<td>MPF</td>
<td>33.23</td>
<td>33.72</td>
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<td>AEMG</td>
<td>40.23</td>
<td>27.89</td>
<td>0.009</td>
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<tr>
<td>Left lower back</td>
<td>MPF</td>
<td>27.5</td>
<td>38.5</td>
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<td></td>
<td>AEMG</td>
<td>35.58</td>
<td>31.76</td>
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</tr>
<tr>
<td>Right lower back</td>
<td>MPF</td>
<td>27.22</td>
<td>38.74</td>
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<td>AEMG</td>
<td>33.78</td>
<td>33.26</td>
<td>0.912</td>
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<tr>
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<td>AEMG</td>
<td>42.73</td>
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<tr>
<td>Right hand</td>
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<td>23.52</td>
<td>41.85</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>AEMG</td>
<td>41.85</td>
<td>26.54</td>
<td>0.001</td>
</tr>
<tr>
<td>Left leg</td>
<td>MPF</td>
<td>28.78</td>
<td>37.43</td>
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<td></td>
<td>AEMG</td>
<td>31.92</td>
<td>34.82</td>
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<tr>
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<td></td>
<td>AEMG</td>
<td>32.08</td>
<td>34.68</td>
<td>0.582</td>
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</table>

4. Discussion
Fatigue occurs as a result of the internal reaction of the muscular system to the external forces of the external load or repetitive tasks associated with the working condition (Lanfranchi and Duveau 2008). Increase in AEMG and decrease in MPF are reported to be an indication of fatigue (Ohashi et al. 2008). However, the value of the change in EMG frequency in this study did not identify significant fatigue, as the value was not within the 12-23Hz frequency band recommended (Nimbarte et al. 2013). This lack of significant evidence of fatigue may be due to the 1 hour test duration which may be too short for significant fatigue to occur (Durkin et al. 2006). This period might still be sufficient for effective posture adjustment, due to the workers' ability to identify regions of discomfort, thereby altering posture for comfort (Ohashi et al. 2008). Workers' adaption to tasks within the period can also reduce muscular activity (Ohashi et al. 2008). It is also possible that some of the workers will adjust their workstation when discomfort becomes significant (Vink et al. 2009). Another factor that might be responsible for the unobserved fatigue might be changes in body temperature which has been reported to affect EMG frequencies (Petrofsky 1979, Durkin et al. 2006). This temperature effect could not be eliminated because measurement commences after workers’ rest period, and the working period might increase body temperature over time.

In this study, musculoskeletal disorders could not be limited to a particular posture. Prolonged sitting has been identified as a risk factor for low back pain, and yet, task design based on prolonged sitting has been increasing (Schinkel-Ivy et al. 2013). Other studies have also identified prolonged standing as the most significant predictor of MSD (Tissot et al. 2009, Marshall et al. 2011). In this study, sitting workers revealed a higher level of muscular activities in the upper body regions of the neck and the upper back, while there were higher activities among standing workers in the lower body region of the lower back and the leg. Generally, male standing workers also maintained stable muscular activities than women as revealed in the slope of the graphs. The slope of the graphs reveals that women are more susceptible to fatigue than men. Significant higher magnitude of muscular activities and MSD prevalence in women than men had previously been reported in the literature (Treaster and Burr 2004, Messing et al. 2008). While most studies have identified significant activity leading to fatigue at the lower back of both standing and sitting workers, there was no fatigue identified in this study within the one hour duration. The steady reduction in muscle frequency in the lower leg or calf, which is an indication of the setting in of fatigue, agrees with what has been reported in the literature (Messing et al. 2008).

The significant differences in interpretation of AEMG and MPF findings in most of the body regions evaluated in this study have also been observed in other studies (Durkin et al. 2006, Ohashi et al. 2008). While there are significant differences in muscular activities (AEMG) between standing and sitting workers in all body regions, except at the lower back, MPF only reported significant difference at the lower back and the hands. Within the one hour working period, no significant gender difference was also observed in both EMG indices except at the left upper back. This is therefore the possibility that gender difference inherit in different tasks may not be significant within an hour. Hence, the less presence of fatigue after an hour for both standing and sitting posture may serve as suggestive intervention that can reduce the occurrence of musculoskeletal disorder in different body regions. Since repetitive tasks and prolonged tasks duration at static posture has been identified as major risk factors, the introduction of regular break of short duration after an hour will introduce flexibility into operations and alter working postures, thereby reducing the possibility of musculoskeletal disorders or injuries occurring. Although this interruption might reduce active time, the reduction in fatigue occurrence will lead to increase productivity and save cost associated with treatment of MSD and loss man-hour.

The lack of direct access to the workers, due to companies’ privacy policy, did not permit real-time assessment of the postural alteration during work. It will also be difficult to conclude on interaction of gender in the occurrence of fatigue in this study because of low statistical power from the sample size. This is not sufficient to undermine the findings in this study since experimentation using EMG are also credible with low sample size (Dankaerts et al. 2004, De Luca et al. 2012, Haddad and Mirka 2013). Since ergonomics findings are mainly based on preponderance of findings, there is need to carry out more study that will cut across different manufacturing sector, investigate the interaction of different demographic variables with occurrence of fatigue.
5. Conclusion

The study observed that both standing and sitting workers did not demonstrate any significant sign of fatigue after working for an hour. Therefore, organisations may introduce few minutes’ posture manoeuvre or exercise every hour, to allow workers flex their muscles and alternate their work posture, so as to accommodate variation in work posture. This is likely to relax the muscles and reduce the possibilities of fatigue setting in early while working. However, the effect of muscle temperature and workers’ anthropometry, needed to identify the level of furniture mismatch, could not be evaluated in this study because of organisational constraint. So also is the direct observation of the postural inclination while working. The investigation of these activities will also help to provide more details that could help in arriving at optimal working time.

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References


