A Comparison of the Effect of Using Sit/stand Stool on Prolonged Standing Task

Sari Julia Sartika and Siti Zawiah Dawal

***Abstract*—Research has shown that prolonged standing associated with pain and fatigue. One of the recommended ways to address them is to use sit/stand stool at the standing workstations. The purpose of this study is to investigate the effect of sit/stand stool on the workstation to reduce standing fatigue. Sixteen subjects involved in the study. Eight females and eight males, with no previous lower extremity problems sorted by picking and placing objects in grading table while (1) standing and (2) using sit/stand stool for 90 minutes. Using sit/stand stool involves a pronounced reduction of percentage of maximum voluntary contraction (%MVC) of muscles and perceived discomfort, increase change of skin temperature, increased change of the circumference at the ankle and calf. Sit/stand stool caused most discomfort in hips. While, for standing condition most discomfort occurred in the foot.**

***Index Terms*— Electromyography, standing, sit/stand stool, fatigue.**

I. Introduction

Most work requires a standing position for manual operation for most of the working day. Some manufacturing locations have tried to eliminate seating as part of a “lean production” program, even if the job still involves static standing rather than constant moving, as in the classic application of lean production. Studies have revealed that quiet standing (QS) involves complex muscular dynamics to stabilize the basically unstable human inverted pendulum (HIP) [1].

Standing work position gives some advantages, such as reach is greater than sitting, body weight can be used to exert forces, requires less legroom, lumber disk pressure are lower, standing can be maintained with little muscular activity and trunk muscle power is twice as great in standing as in semi standing or sitting [2]. However, standing works cause leg swelling and long-term leg swelling increases the risk of developing pathological reaction such as varicose veins, thrombosis and pulmonary embolism (winkel, 1987 as quoted by Kawano, 2005 [3]). Prolonged standing has been associated with the onset of low back pain symptoms in working populations [4]. Gregory and Callaghan (2008) reported that around 50% of healthy subjects perceived low back discomfort after 2 hours of prolonged standing [5].

There are some recommended methods in reducing the standing fatigue during prolong standing. One of these methods is providing sit/stand stool at the workstation [6]. A workstation that includes an optional seat (chair, sit/stand stool) and some kind of footrest increases the variety of body positions and encourages frequent changes between them [7].

Researchers have monitored some variables during prolonged standing; however it focus on the comparison of flooring (soft versus hard floor) and type of shoes with limited muscle selection recorded. The investigation of sit/stand stool is limited and rare. It only distress on leg swelling and perceived discomfort. Thus, the purpose of this study is to investigate the effect of using sit/stand stool on the workstation to reduce standing based on EMG, skin temperature and perceived discomfort.

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II. Methodology

A. Subjects

Sixteen subjects (eight females and eight males) participated in this experiment, with aged between 23-29 years old and currently in good health conditions. All subjects had no history of lower extremity problems.

B. Apparatus and Material

There were subjective and objective measurements. The objective measurements were EMG recordings, skin temperature and ankle and calf circumference. The subjective measurement was perceived discomfort using the Borg CR 10 scales.

NORAXON EMG and the sensor system were used to measure muscles activity. Electrodes were pasted on selected muscles, and they were connected to a transmitter, TeleMyo 2400T G2-290, using the EMG cable. The transmitter with 8 channels (only 4 channels needed) and the wireless system sent the EMG signal to the EMG software, MyoResearch XP Master Edition. A Lutron infrared thermometer (TM-956, range -30^{o}C to 305 ^{o}C, 0.95 emissivity value) was used to record the skin temperature.

Gullick II tape (Country Technology, Inc., Wisconsin, USA) was used to measure the ankle circumference (every 15 minutes) and calf (before and after the experiment). Toys with different colors were used as the experimental object

C. Procedures

Subjects performed a sorting task in front of a grading table by picking and placing objects for 90 minutes for each condition (using footrest and sit/stand stool). Subjects were required to stand in a limited working space (0.5 m x 0.5 m)

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while performing the sorting task. There was no rest given during the experiment, but the subjects were allowed to adjust their posture within the constrained space. All subjects stood bare foot.

Fig. 2 shows the workstation. The dimensions of the workstation were within the limit of a normal horizontal work area (for a lower table) and maximum horizontal work area (for the grading table). The reach envelope (normal and maximum area) depends on the subjects' anthropometric measurements.

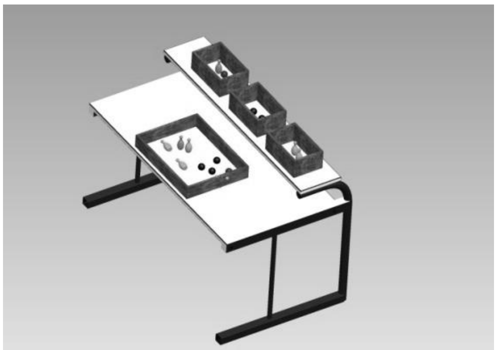

Figure 2. Workstation

Subjects sorted mixed objects and placed them in three target boxes on the grading table. The first box was for green objects, the second box was for blue objects and the third box was for other color objects. The duration of each pick and place was three seconds. Each subject was required to perform the same task. Fig. 3 shows the experimental task. Experiment 1 was standing and experiment 2 was using sit/stand stool.

Four lower leg muscles (soleus, medial gastrocnemius, lateral gastrocnemius, tibialis anterior) and two back muscles (Lumbar erector spinae (LES) and Thoracic erector spinae (TES)) were chosen for experiment.

Figure 3. Experimetal task

D. *Measurement and Data Collection*

Muscles activity was recorded with surface EMG through disposable electrodes. Electrodes position was based on Surface EMG for non-invasive assessment of muscles (SENIAM) [8]. These individual recommendations were based on 2 general recommendations. First, with respect to the longitudinal location of the sensor on the muscle, SENIAM recommends to place the sensor halfway the (most) distal motor endplate zone and the distal tendon. Second, with respect to the transversal location of the sensor on the muscle SENIAM recommends to place the sensor at the surface away from the 'edge' with other subdivisions or muscles so that the geometrical distance of the muscle to these subdivisions and other muscles was maximized. On the other word, the electrode pair in a central position over the muscle belly.

Raw EMG was collected at 1500 samples/s. ECG bursts that may contaminate EMG recording were cleaned by ECG reduction for recording at upper body. Digitals filtering were used at 10Hz-400Hz. Full wave rectifications were used to convert negative amplitude to positive amplitudes in order to remove the systematic bias. The non-reproducible part of the signal was minimized by applying digital smoothing algorithms RMS (root mean square) that outline the mean trend of signal development.

To overcome the vary of electrode sites, subjects and even day to day measures of the same muscle site was the normalization to Maximum voluntary contraction (MVC) that calibrate the microvolts value to percent of maximum innervations capacity. Subjects performed maximal voluntary contractions (MVC) tests before the experiment, with specific positions [9]. The MVC tests were measured for three seconds repeated three times.

Skin temperatures were taken at the beginning and every 15 minutes at the selected lower leg muscles, dorsal arch and elbow (as control temperature). Circumference at the ankle measured every 15 minutes and at the calf before and after experiment.

Perceived discomfort for general fatigue, discomfort on upper back, lower back, hips, upper leg, knee, lower leg, ankle and foot were rated by subjects using Borg CR 10 scales at the beginning and every 30 minutes while experiments.

E. *Data Analysis*

Paired t-tests were used to investigate the significant difference for % MVC of EMG, changed of skin temperature, changed in calf and ankle circumferences and perceived discomfort between the two conditions. Correlation analyses were used to determine the strength of the relationship between %MVC for each muscles with time.

III. RESULTS

A. *Subjects anthropometry data*

The anthropometric data regarding body dimensions for the standing workstation shows in Table 1.

Table 1. Subjects anthropometry data

	Male (n=8)		**Female (n=8)**	
	mean	**SD**	**mean**	**SD**
Age (years)	24.6	1.51	25.5	1.18
Height (m)	169	9.38	155.36	2.93
Mass (kg)	70.25	23.8	50.7	6.7
Standing elbow height (cm)	104.9	6.2	95.13	1.8
Arm reach forward (cm)	84.9	14.4	77.38	5.89

B. *The effect of 90 minutes standing*

1) *Percent MVC of EMG*

Ninety minutes of standing work increase the %MVC of EMG. The increase in the soleus was 80.81%, the medial gastrocnemius was 83.33%, the lateral gastrocnemius was 63.22%, the tibialis anterior was 85.2%, the peroneus was 80.12%, the LES was 71.02% and the TES was 33.26%.

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Studies by Bjorksten and Jonsson (1977) reported that when the period of muscle contraction exceeds an hour, the endurance limit of force may be as low as 8% MVC. This value is characterized as fatigue. Fatigue in the soleus muscle occurs in the first 5 minutes of standing. However, in the peroneus, LES and TES, fatigue occurs after 45 minutes, 30 minutes and 35 minutes, respectively.

Correlation analysis was used to find the correlation between %MVC for each muscle and time. The analysis found There was correlation between the soleus (r= 0.97, p= 0.00), medial gastrocnemius (r= 0.98, p= 0.00), lateral gastrocnemius (r= 0.96, p= 0.00), tibialis anterior (r=0.93, p=0.00), peroneus (r= 0.98, p= 0.00), LES (r=0.98, p=0.00) and TES (r=0.92, p=0.00) and time. The increase of %MVC was in positive direction.

Figure 3 shows the graph of %MVC over 90 minutes (ninety minutes of exposure time was divided to 18 time intervals, each time interval was 5 minutes).

The greatest muscle activity occurred in the soleus muscles, which also had the highest mean %MVC for lower leg muscles.

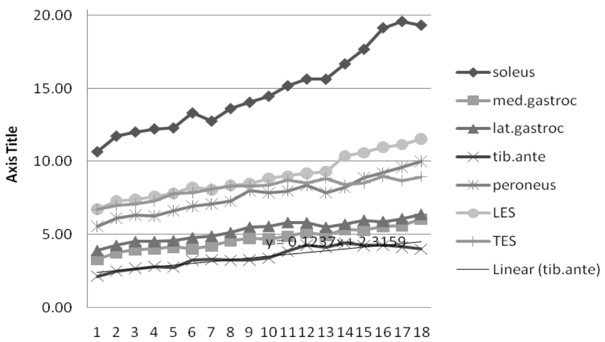

Figure 3. Mean of % MVC of EMG while standing for 90 minutes

2) Changes in skin temperature

For 90 minutes, the change in the normalized (to elbow control temperature) skin temperature over muscles and dorsal arch is shows in figure 4. The change in normalized skin temperature in the soleus was 91%, in the medial gastrocnemius was 312%, in the lateral gastrocnemius was 7.6% , in the tibialis anterior was 44%, in the peroneus was 136% , and in the dorsal arch was 576% after 90 minutes.

Correlation analysis found There was a strong correlation between changed of skin temperature at soleus (r= 0.92, p=0.04), medial gastrocnemius (r= 0.92, p= 0.004) and dorsal arch (r=0.95, p= 0.001). Positive correlation means that the changed of skin temperature at dorsal arch tend to increase while 90 minutes standing.

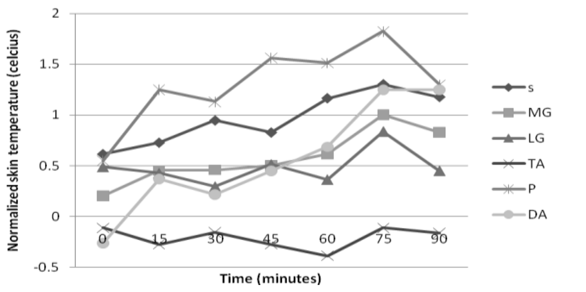

Figure 4. Changed of skin temperature while standing for 90 minutes

3) The changes in calf and ankle circumference

The changes in leg and ankle circumferences were based on the circumference at the beginning of the experiment (0 minutes). Mean changes in calf circumference before and after 90 minutes standing was 0.44 cm. Furthermore, changes in ankle circumference increased 459.1%, from 0.1 cm after the first 15 minutes to 0.8 cm after standing for 90 minutes.

4) Perceived discomfort

The greatest discomfort occurred in the foot. Discomfort changed overtime and significantly difference between before and after, for all body parts. Discomfort increased over time for all body parts. The increased mean perceived discomfort between the first 30 minutes and after 90 minutes of standing for general fatigue was 152% , for the upper back was 169% , for the lower back was 126%, for the hips was 217%, for the upper leg was 179%, for the knee was 141%, for the lower leg was 126%, for the ankle was 127% and for the foot was 137% .Figure 5 shows the mean of perceived discomfort. Figure 5 shows the changes in perceived discomfort.

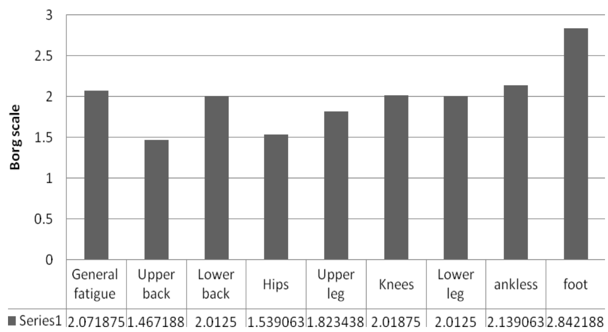

Figure 5. Mean of perceived discomfort for all body part after 90 minutes standing

C. Comparison Standing with Sit/stand Stool

The mean %MVC standing was greater than that using a sit/stand stool. Figure 6 shows the difference between these two conditions. The paired t-test was used to find the difference in the mean %MVC between the two conditions. The result showed that there were significant difference in the mean %MVC in the soleus (p= 0.002), medial gastrocnemius (p=0.008) and lateral gastrocnemius (p=0.007).

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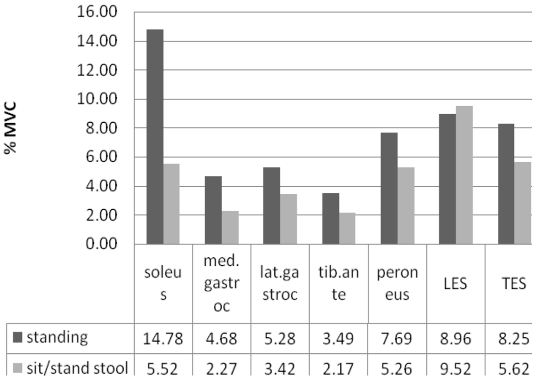

Figure 6. Mean of %MVC standing versus sit/stand stool

Changes in skin temperature over the muscles showed that those for the sit/stand stool were greater than those for the standing condition. Figure7 shows the difference in these two conditions. The paired t-test was used to find the difference in the mean changes in skin temperature between the two conditions. The result shows that there were significantly different mean %MVC in the soleus (p= 0.032) and tibialis anterior (p=0.024).

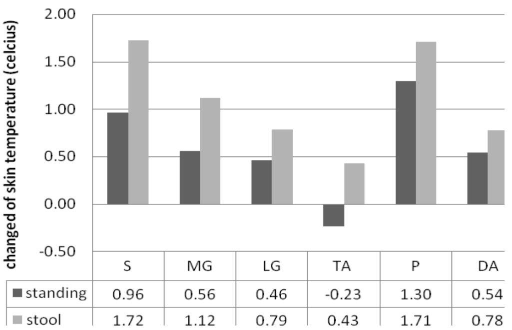

Figure 7. Mean of changed of skin temperature standing versus sit/stand stool

The mean change in calf circumference was greater using the sit/stand stool. The calf circumeference for standing is 0.44, while for using sit/stand stool is 0.67 The mean change in ankle circumference was also greater using the sit/stand stool. Fig. 8 shows the different of these two conditions.

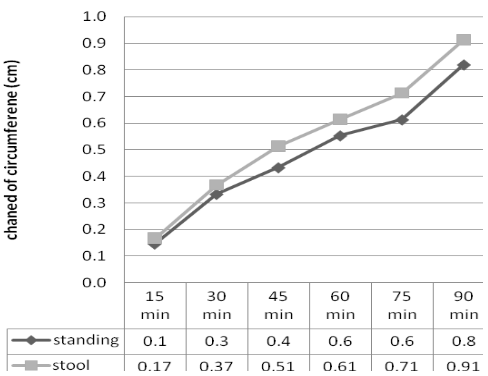

Figure 8. Mean of ankle circumference changes standing versus sit/stand stool

Perceived discomfort of body parts and general fatigue are greater in the standing condition (Fig. 9). However, perceived discomfort in the hips and upper leg are higher while using the sit/stand stool. The paired t-test was used to find the mean changes on perceived discomfort between the two conditions. The result indicated that there was a significant difference in hips (p=0.009), knee (p=0.019), lower leg (p=0.004), ankle (0.011) and foot (p=0.009)

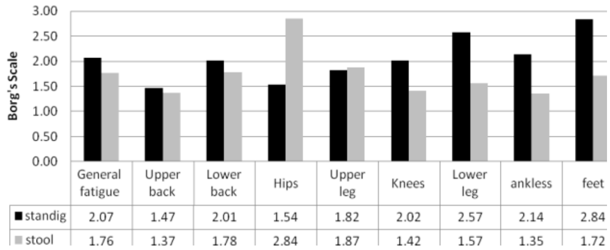

Figure 9. Mean of perceived discomfort standing vs using sit/stand stool

IV. Discussion

A. *Standing*

Surface EMG techniques have been extensively applied to analyze muscle activity [5, 10, 11, 12, 13, and 14]. Several studies used EMG recordings to assess the effect of flooring on local muscle fatigue in the legs or back, with varied methods.

The present study showed during the 90 minutes of standing, muscles %MVC increased. As for back muscle, LES has the higher mean of %MVC. This indicates people tend to lean the body backward while standing for long time. This posture occurred to release the discomfort. These results were in line with the result another study that found fatigue occurred with an increase in normalized RMS or %MVC [15, 16]

Skin temperature at dorsal arch tends to increase while 90 minutes standing. Arches contribute to the strength, stability, mobility, resilience of the foot and also the lower part of the body. Therefore, the pooling was greatest at this part. During standing and other leg activities, the arches serves as shock absorbers, by spreading energy before it is transferred higher up to leg. Skin temperature has been suggested to reflect muscle fatigue [5, 11, and 13]. Increases in a lower limb skin temperature while standing on the hard surfaces and a decrease while standing on the soft surfaces have been reported by Madeleine and Arendt-Nielsen (1998) [13].

Changes in ankle circumference increased. Swelling which can be investigates by the leg volume or circumference changing also reflects fatigue [13, 17, 18, 19].

B. *Standing Vs Sit/stand stool*

The present study shows that using sit/stand stool in standing work increases the %MVC of lower leg muscles compared to that for standing alone. Fatigue only occurred in the hips after 15 minutes using the sit/stand stool. The idea of using a sit/stand stool is to maintain a standing position, but the stool supports the body weight. The reduction of %MVC of the muscles indicated that the stool supported the body weight instead of the lower extremities.

Using a sit/stand stool also increased the skin temperature. Moreover, the changes in skin temperature over the muscles showed that the sit/stand stool caused higher temperatures than the standing condition because of problems with blood circulation in the lower extremities. Problems with blood

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circulation cause swelling or increase the circumference and skin temperature.

Mean changes in calf and ankle circumferences were greater using the sit/stand stool. The hydrostatic pressure is higher using the sit/stand stool, and the seat of the sit/stand stool might compress the vein in the thigh and hip areas. This causes poor circulation to the legs. This result matches that of Chester et al. (2002) [18]

However, the perceived discomfort of all body parts and general fatigue showed that using the sit/stand stool was lower than that for standing, except for the hips and upper leg. This is also related to posture, and the sit/stand itself may have a hard seat. Although the sit/stand stool supports the body weight, the seat was hard because the base was made from wood and the cushions were not thick. When using the sit/stand stool, some parts of the upper leg were supported by the seat of the stool. This position, over a long time, increases discomfort in the upper leg.

V. Conclusion

Within the scope of this study, it can be concluded that:

1. Prolonged standing for 90 minutes develops fatigue in the lower leg and back pain. Muscle fatigue occurred in the soleus (after 5 minutes), LES (after 30 minutes) and TES (after 35 minutes).
2. The soleus is the most active muscle during prolonged standing, whereas, the tibialis anterior has the least active muscles. Thus, people have a tendency to lean their body backward, to release pain and discomfort while standing for long time
3. The mean percent MVC and perceived discomfort while using a sit/stand stool were lower than for standing, but there was higher perceived discomfort in the hips and upper leg. In addition, fatigue began in the lower back after 15 minutes.
4. Using sit/stand stool in standing work involves a pronounced reduction of %MVC of muscles and perceived discomfort, increase changed of skin temperature, increased changed of the circumference at the ankle and calf.
5. Sit/stand stool caused most discomfort at hips. While standing cause most discomfort at foot.

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