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Effect of Tool Weight and Hand Posture on the Postural Tremor of the Upper Extremity

Jae Young Kim* · Ho Young Song** · Myung Hwan Yun*** · Myun W Yun*

ABSTRACT

In light-weight hand tools, static posture may result in postural fatigue.

Postural tremor of the upper extremity in a static posture was measured to provide guidelines for hand tool weight. Postural tremor was measured on five levels of tool weight : no weight, 400g, 800g, 1200g, and 1600g. Three types of camcorder recording postures were selected.

For each condition, postural tremor was measured together with ENG of biceps, deltoid and pectoralis major, and Borg's CR-20 ratings of perceved exertion.

Results of the experiment are as follows : frequency analysis of tremor revealed increased amplitude of frequency bands of 2-4Hz and 10-14Hz. Postural tremor of the upper extremeity maintained the initial level until fatigue developed. After the development of fatigue, the rate of change of postural tremor significantly increased. Different tool weights and hand postures showed different rates of tremor increase. Time to fatigue and corresaponding endurance time were positively correlated with Borg's RPE scores.

Keywords : Postural Tremor, Hand Tool, Upper Extremity, Subjective Fatigue

* Dept. of Industrial Engineering, Seoul National University
** Samsung Data Systems Co. Ltd
*** Dept. of Industrial Engineering, Pohang University of Science and Technology

I. Introduction

People use their hands when they control actions. Bad tool design or constant repetition of a task may result in cumulative trauma disorder of the hand or wrist. Many studies have concentrated on the effects of tool weight on the tasks of manual material handling or dynamic control.

These days, hand tools are more automated and light-weighted. As a result they need much less manual forces. Many new hand tools are being introucued into the market (Akita, 1991 ; Chang, 1992). Their designs are task-oriented, which result in varied shapes and enhanced performance. In consumer product design, the main issue is reduction of user discomfort.

Many studies have been published to provide guidelines for hand tool design, especially for the shape, size, and weight of the hand tools(Armstrong et al., 1982 ; Gallagher et al., 1991). Tasks which require precision or static posture, even when the tool is light, may result in muscle fatigue, postural tremor and/or decrease of endurance time, precision and performance because of continuous static postural stress (Milerad et al., 1991 ; Chaffin, 1976). Therfore there is a need for hand tool design guidelines in static and precise tasks, which may be different from those for dynamic tasks.

In this, experiment was performed to measure the postural tremor based on the postures which are typical for camcorder recording. The subjective fatigue level and EMG were measured simultaneously. The results revealed the effect of tool weight in static posture and precision tasks ; in addition, a relationship was found between postural tremor, subjective fatigue and EMG.

2. Method

<u>Backgrounds</u>

Eegonomic design of hand tools can prevent work accidents, reduce workload and increase task performance. Hand tools should be designed to enhance user satisfaction with respect to task requirements, individual characteristics, and environmental characteristics (Anderson, 1985). Postural fatigue in static posture may result from unsupported body segment. It is the cause of passive tension in soft tissue, disturbance of blood flow and subjective discom-fort(Sanders and McCormick, 1992 ; Konz, 1983 ; Singleton, 1982). In precision task, maintenance of static posture will have effects on task performance.

Postural tremor can be defined as the involuntary oscillation of a body limb which a person attempts to hold steady. Some studies suggest that postural tremor is affected by heart rate, visual correction process, neuromuscular activity, fatigue and neurotoxic substances (Wiker et al., 1989 ; Kaudewitz, 1977). It may be difficult to measure the static postural fatigue using general physiological indices such as subjective discomfort rating and/or postural tremor. In the case of fatigue induced by light tools, tremor and subjective discomfort rating can be a more precise measure than EMG amplitude(Giroux, 1992 ; Wiker et al., 1989).

Camcorder is a typical hand tool which requires a continuous static posture and precision. By the progress of technology, manufacturers have devised electronic image stabilizers to improve the image quality which is affected by the postural tremor. In current commercialized camcorders, these devices eliminate the picture shake in the range of 5~20Hz. However users want more effective stabilizer in order to relax the recording posture. In a previous study, average recording time was found to be 15~30 minutes in average (Lee et al., 1994). Although camcorder weight is 800~900g, users were reluctant to maintain the static recording posture and it causes postural tremor.

Subject and Equipment

Subjects were five university student volunteers (age : 20~25), who had not experienced musculoskeletal disease. They are all right-handed. The tool used in the experiment was a 60×90×140mm cubic-shaped box, which is similar to the viewfinder-type camcorder sold in the market. The weight levels are chosen as 0, 400, 800, 1200 and 1600g, since the weight of hand tools which require precision and static posture such as camcorder and solder is below this level. Postural tremor was measured using an accelerometer (B&K type 4366), processed by preamplifier (B&K type 2626, level : 1V/g), and recorded on a PC. Electromyograph and preamplifier (×1000) was used for the measurement of EMG, which were made at Precision Insturmentation Center in Seoul National University. The data were made at Precision Instrumentation Center in Seoul National University. The data were processed by A/D board and transmitted into the PC.

Procedure

The camcorder recording postures were selected to simulate the real situation, characterized by 50, 80, 120 degrees of elbow angle and 30 degrees of shoulder angle (Figure 1). The postures were determined by consideration of the viewfinder-type camcorder and viewcam-type camcorder, which are sold in the

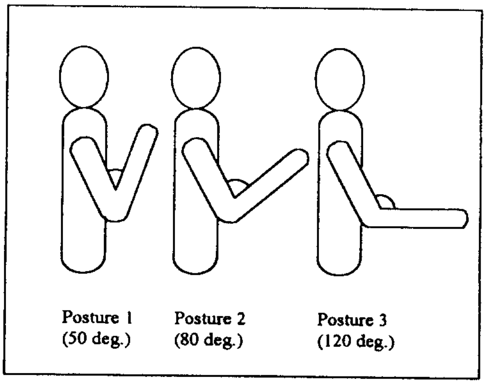

Fig 1. Postures of the Experiment

market. Posture 1 and 2 are for the viewfinder-type and posture 3 is for the viewcam-type.

Before the experiment, the MVC (maximum voluntary contraction) of each subject was measured, which was in the range of 20~26kg. Tool weights of the experiment were in the range of 10% MVC of the subjects.

In this experiment, full factorial design was used. There were 15 experimental conditions, whose sequence was randomized. To reduce the fatigue effects, experimental trials were only performed twice per day. Electrodes were attached on the biceps, deltoid, and pectoralis major. During the experiment, the subject was seated on the muscular strength tester (TKK 1216) and performed the predetermined task, which was to position one keeping 2mm-diameter pin in the target of 4mm-diameter. Tool was grasped at right hand, which was the same as usual camcorder grasp (It is similar to palm grasp). Postural tremor was sampled for 10 seconds per minute (sampling rate : 200Hz) and RPE was measured every five minutes. EMG was recorede 10 seconds per minute (sampling rate : 1000Hz). The task ended when the subject reported his fatigure level was 'very very hard'. This trial time of the task was operatonally defined as task endurance time.

3. Results

Postuaral Tremeor

Postural tremor was converted into its RMS value and calculated as the postural tremor level with respect to its initial value in order to eliminate day effect and user difference (Equation 1). The results showed that the level kept its initial value and then increased linerarly at some point. Figure 2 is an example which was recorded in the condition of 80 degrees elbow angle and 800g tool. This turning point was defined as time to fatigue and measured by the time at which its level was outside 3 standard deviations of the initial tremor level.

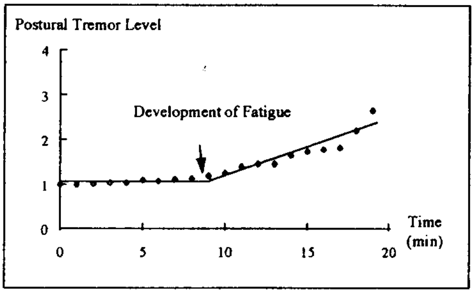

Fig 2. Change of Postural Tremor Level

$$\textit{Postural Tremor Level} = \frac{\textit{RMS Value of Measured Tremor}}{\textit{RMS Value of Initial Tremor}}$$

(Equation 1)

The change pattern of postural tremor level between development of fatigue and posture endurance time was analyzed by stepwise regression (Table 1). It was found that as weight increased, the postural tremor level also increased, especially for the 1600g tool the increasing rate was 0.3 times/min.

Table 1. Regression Analysis of Postural Tremor Level.

Weight	Posture 1		Posture 2		Posture 3	
	Slope	Corr. Coeff.	Slope	Corr. Coeff.	Slope	Corr. Coeff.
0g	0.06	0.73	0.07	0.40	0.12	0.48
400g	0.10	0.62	0.10	0.47	0.15	0.71
800g	0.12	0.25	0.18	0.98	0.20	0.86
1200g	0.14	0.59	0.32	0.88	0.24	0.80
1600g	0.13	0.69	0.35	0.89	0.39	0.92

In the frequency analysis of the postural tremor, it was observed that there was much more amplitude change in the frequency range of 2~4Hz and 10~14Hz(Figure3). However, frequency shift was not so significant. With respect to the previous studies the amplitude increase in 10~14Hz might be affected by the feedback of neuromuscular system. It was thought that the effect of postural fatigue on the tremor was concentrated on increased amplitude in the range of 2~4Hz and 10~14Hz.

Task Endurance, subjective Fatigue Level and Emg

Each trial was performed until the subject reported his fatigue level as 'very very hard'. Tool weight had a significant effect on the task endurance time ($p<0.05$) and posture effect was not significant (Figure 4). However, time to

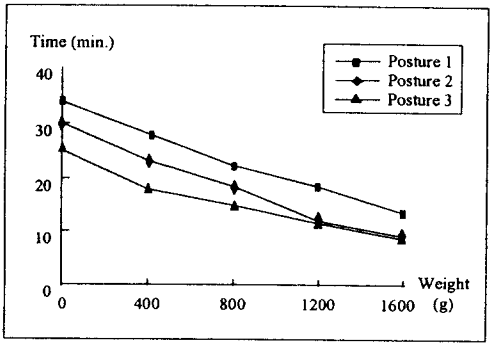

Fig 4. Task Endurance Time

fatigue was significantly affected by bot h tool weight and posture ($p<0.05$). Tim e to fatigue was found to be 1/2~2/3 of the task enduance time.

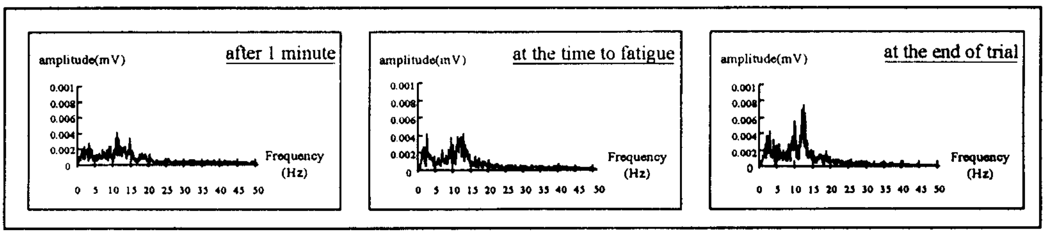

Fig 3. Frequency Analysis of Tremor

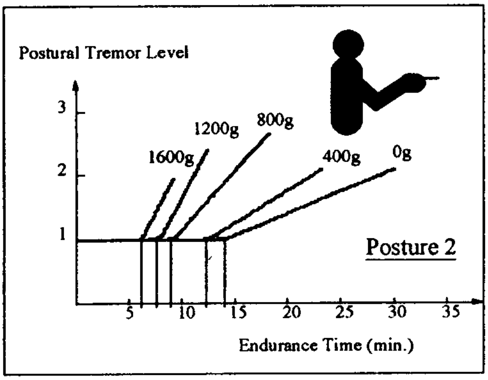

Fig 5. Postural Tremor Level

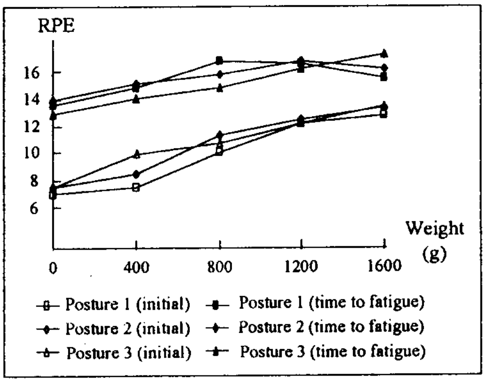

Fig 6. Change of RPE

Subjective fatigue level was evaluated using RPE(rating of perceive exertion) It was observed that there were some-what constant differences between the initial values and the values which was recorded after fatigue developed. The initial values were different depending on posture and weight, but the values at the time of fatigue development were about 3~5 scores higher than their initial values(Figure 6).

Rectifed EMGs of three muscles (biceps, deltoid, pectoralis major) showed different initial values depending on tool weights. As tool weight increased, there was a tendency for rectified EMG to increase. However, as its incremental rate was much lower than that of postural tremor level, it was thought that EMG was not as sensitive a measure of fatigue level of a static task in the case of tools lighter than 1600g(Figure 7)

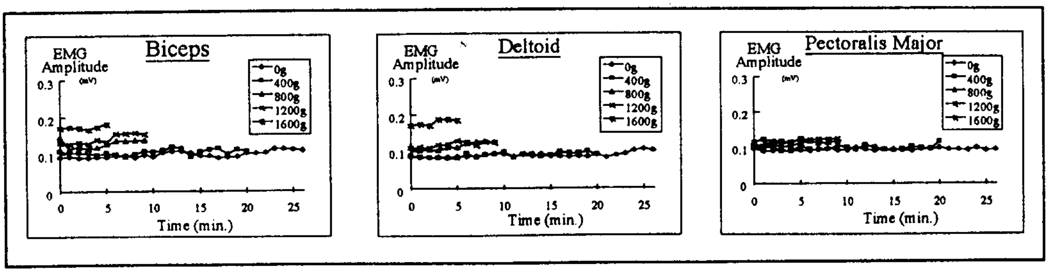

Fig 7. Rectified EMG

4. Conclusion

The differences in tool weights caused a change of the endurance time and time to fatigue in tasks where precision was required. Posture of the upper extremity was another key factor for determining posture maintenance time. The experiment of maintaining static posture revealed that in subjects in their twenties the postural tremor level of the upper extrmeity which was induced by the static workload increased slowly from the initial tremor level after 1/2~2/3 of the total endurance time elapsed. The postrual tremor level increased 10~30% rate every minute after development of fatigue and when using the 1600g tools, increase of the tremor level was much more than 30%.

Since the variation of rectified EMG amplitude was very small, it was not effective as a measure of the fatigue level induced by a light static load. In frequency analysis of the postural tremor, it was found that after the time to fatigue the increase of amplitude in the range of 10~14Hz and 2~Hz was relatively high. But the frequency shift did not take place. The increase of the amplitude in 10~14Hz was the major source of the postural tremor change after fatigue development. Also amplitude change in 2~4Hz might be considered. The RPE at the time of fatigue development was significantly different from the initial RPE. It was found the the estimation of the time to fatigue development and endurance time could be calculated based on the initial RPE value and experimental condition.

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