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Effect of Trunk and Upper Arm Angle on Lifting Capacity

Seong Rok Chang

Department of Safety Engineering, Pukyong National University, Busan 608-739, Korea

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Abstract : Lifting capacity and difficulty of task are influenced by body posture. In RULA and REBA, the body was divided into segments which formed two groups, A and B. Group A includes the upper and lower arm and wrist while group B includes the neck, trunk and legs. This ensures that whole body posture is recorded so that any awkward or constrained posture of the legs, trunk or neck which might influence the posture of the upper limb. This study aimed to measure MVC (maximum voluntary contraction) and subjective judgment in psychophysical method (Borg's scale) according to trunk and upper arm angle and to analyze results statistically. The results of this study were that lifting capacity was more influenced by interaction of body posture rather than angles of each part, and MVC variation according to trunk and upper arms angles should different patterns. This means that we consider the interaction of trunk angles and upper arm angles when we access risk factors of the postures. This survey would be also the basic data to evaluate difficulty of lifting tasks according to body postures ergonomically

Key words : Lifting capacity, MVC, trunk angle, upper arm angle, Borg's scale

1. Introduction

Work-related musculoskeletal disorders (WMSDs) are the leading cause of lost-workday injuries and workers' compensation costs. In American workplace, WMSDs account for 34% of all lost-workday injuries and illnesses, and more than 620,000 lost-workday WMSDs are reported each year. Also, WMSDs account for $1 of every $3 spent for worker' compensation, and each year more than $15~$20 billion in workers' compensation costs (HESIS 2001).

MSDs have been found to be associated with numerous occupational risk factors such as repetition motions, awkward postures, forceful exertions, hand-arm and whole-body vibration, static postures, insufficient rest/recovery periods, and heavy lifting (HESIS 2001). Heinsalmi (1986) and Burdorf *et al.*(1991) pointed out that a significant relationship was found between awkward working postures and musculoskeletal-related lost workdays or low back disorders. Various assessment methods such as Ovaco Working Posture Analysing System (OWAS), Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), etc. are now available for evaluating exposure to the risk caused by awkward working postures (Karhu *et al*. 1977, McAtamney and Corlett 1993, Hignett and McAtamney 2000).

We have executed ergonomics program to prevent WMSDs occurrence in many industries such as DSME, Samsung heavy industry, Ssangyong motor company, LG electronics company (Chang et.al. 2006. Lim et.al. 2006, Lim et.al. 2004, Chang et. al. 2004). Both RULA and REBA was used in assessment of the task hazard. In assessment of awkward working postures, upper arms angle was checked independent on trunk angle by the one part of Group, but there are some interaction on upper arms and trunk angle. We faced the necessity of redesigning task assessment which is concerning upper arms and trunk angle. Thus, this study was performed experiment to survey and analyze a correlation between the task efficiency and body angles through the estimate of maximum voluntary contraction (MVC) and Borg's Scale.

2. Method

2.1 Subject

Twelve subjects were recruited for the study. They were volunteer university students. Their ages ranged

*Corresponding author: srchang@pknu.ac.kr

Table 1. Variables of experiment

Independent variables	Dependent variables
Trunk flexion angles : 0°, 30°, 60°	MVC(NMVC)
Upper arms angles : 110°, 90°, 70°, 45°, 30°, 20°, 0°, -20°, -30°	Borg's CR10 scale

from 22 to 26. None of the twelve subjects had history of musculoskeletal injury of the back or upper extremities. Eleven participants were right-hand dominant and one participant was left-hand dominant. They were familiarized with experiment procedures, the meaning of Borg's scale and MVC before the experiment data were collected.

2.2 Apparatus

For gauging muscular strength, the digital dynamometer produced by Takei Kiki Kogyo(Takei DD1999) was used. This dynamometer expresses the power as digital-number for easy confirming the power which was displayed by the strain-gauge produced by Takei Kiki Kogyo (1269 E).

2.3 Experimental design

The subjects were asked to exercise their MVC under the conditions of task. According to trunk flexion and upper arms angles in using RULA and REBA, trunk flexion (straight posture is 0°) is 0° and 30° and 60°. We estimated MVC after subjects was gripping the bar which was connected to a strain-gauge, lifting up the bar. After each of the onetime experiment, subjects filled in the work sheet of Borg CR10. To express the MVC well, lower arms were fixed from 90° to 100° to give maximum power. For experiment, the variables are shown in Table 1.

3. Results

After getting data, we normalized MVC value to reduce inter-subject variation. The normalization was performed as follows;

$$NMVCijk = \frac{MVCijk}{\text{Maximum of } MVCijk}$$

MVCijk : MVC value in trunk angle i and upper arm angle j of subject k

NMVCijk : Normalized MVC value in trunk angle i and upper arm angle j of subject k

The results of experiment were shown in Fig. 1~3. Fig. 1 showed that there was a little variation in NMVC according to upper arm angle in trunk angle 0°. Fig. 2 (in trunk angle 30°) and Fig. 3 (in trunk angle 60°) showed that there were significant variations in NMVC according to upper arm angle. When upper arm angle is -30°, NMVC was the maximum. Especially, there is rapid increase between 0° to -30°. This means

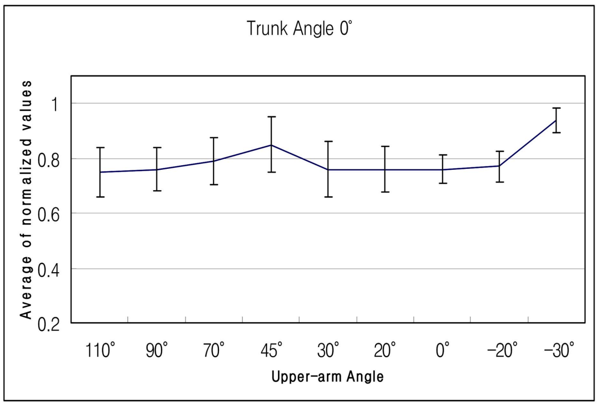

Fig. 1. Average of normalized values of MVC in Trunk Angle 0°

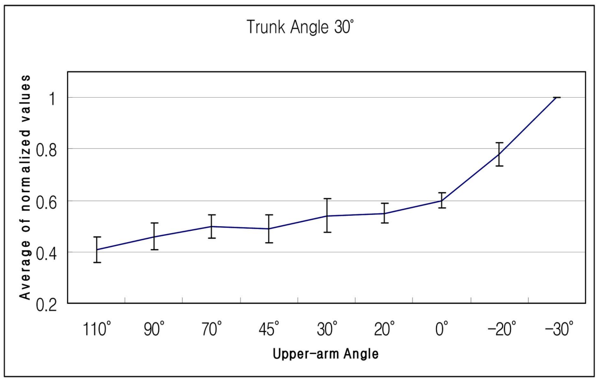

Fig. 2. Average of normalized values of MVC in Trunk Angle 30°

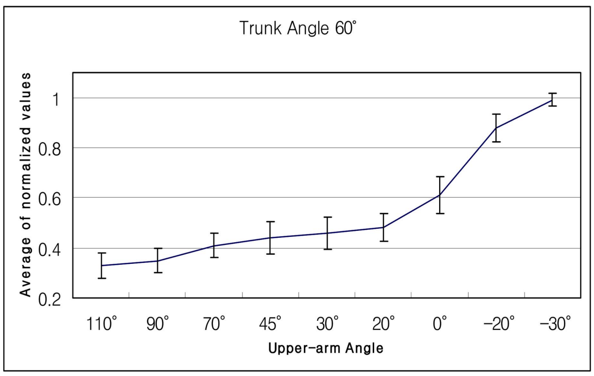

Fig. 3. Average of normalized values of MVC in Trunk Angle 60°

Table 2. Average of Borg's CR10 scale

		Trunk Angle		
		0°	30°	60°
Upper-arm Angle	110°	5.77	6.58	8.08
	90°	4.92	5.83	7.75
	70°	4.25	6.00	7.42
	45°	3.75	5.17	7.08
	30°	3.33	4.67	6.5
	20°	3.00	5.17	6.75
	0°	3.17	4.75	5.83
	-20°	3.42	4.92	4.75
	-30°	3.33	4.58	4.50

that lifting capacity is determined by location of materials handled.

As mentioned above, Borg's CR10 scale data were measured psychophysical estimate for the correlation between trunk angles and upper arms angles. According to the upper arms angles, in trunk angles (0°, 30°, 60°), Borg's CR10 scale data are in the Table 2. Result of Borg's CR10 scale showed that data was least when upper arm angle were -30° in trunk angle 30° and 60°. This means that subjective rating at upper arm angle -30° was less strong rather than that at upper arm angle 0°.

These results are different from RULA and REBA. In RULA and REBA, the assessment rating is lowest at upper arms angle 0°. In bending posture, the experimental results show that the interaction of trunk angle and upper arm angle must be considered.

4. Conclusions and Discussion

MVC and Borg's CR10 scale were measured under static lifting task according to trunk and upper arm angles. The results of the study revealed as follow.

1) The MVC appeared to be linearly increasing as upper arm angle was decreased. In general, RULA and REBA have mentioned that the load of the task is increasing when upper arm angle gets away from 0°. However, in this experiment, MVC was increased when upper arm angle got away from 0°.

2) Especially in trunk flexion angles 30° and 60°, MVC was rapidly increasing when upper arm angle varied from 0° to -30°. Therefore, MVC is relatively changed by interaction of trunk and upper arm angle.

3) From the result of experiments, data of Borg's CR10 scale is different from rating of RULA and REBA. Because of interaction of trunk and upper arms angles, we can reduce work load by making a suitable interaction among the body angles. Therefore, Borg's CR10 scale was affected by the working posture rather than each angle of body.

Based on the result of this study, it is suggested that in posture assessment using RULA and REBA we consider the interaction of trunk angles and upper arm angles. In addition, we need to estimate more variables than before, and to add other methods measuring the load of tasks quantitatively.

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