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Leslie J.K. Fountain[a]
[a] System Concepts, United Kingdom
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Examining RULA's Postural Scoring System With Selected Physiological and Psychophysiological Measures

Leslie J.K. Fountain

System Concepts, United Kingdom

The Rapid Upper Limb Assessment (RULA) survey is a posture-sampling tool used specifically to examine the level of risk associated with upper limb disorders of individual workers. This paper examines the relationship between RULA's postural scoring system and measures of surface electromyography (EMG), self-reports of discomfort, and job attitude questionnaires. Twenty participants each performed a 30-min typing task on a computer in 3 working postures based on RULA's scoring system. A statistically significant difference was found only in perceived discomfort. The perceived discomfort results demonstrated that RULA was able to identify "high risk" postures. The next question we need to ask is, does perceived discomfort result in tissue damage, or does tissue damage yield discomfort?

RULA upper limb disorders musculoskeletal disorders working postures EMG perceived discomfort job attitude

1. INTRODUCTION

Musculoskeletal disorders (MSDs) are an increasing health risk facing office employees today. The Health and Safety Commission developed a priority programme targeted to reduce the incidence of MSDs as well as lost working days due to MSDs (Health and Safety Executive, 2002). Therefore, a "gold

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Correspondence and requests for offprints should be sent to Leslie J.K. Fountain, System Concepts, 2 Savoy Court, London WC2R 0EZ, United Kingdom. E-mail: <leslie@system-concepts.com>.

standard" is required that would effectively identify risk factors, estimate the true magnitude of risk, and systematically evaluate the efficacy of prevention and return to work programmes. The research presented in this paper contributes to the achievement of this goal.

The Rapid Upper Limb Assessment (RULA) survey, designed by McAtamney and Corlett (1993), is a posture sampling tool used specifically to examine the level of risk associated with upper limb disorders of individual workers. RULA was based on an extensive literature review in order to determine the load at which tissue damage would result. This paper examines the relationship between RULA's postural scoring system and the physiological measurement technique of surface electromyography (EMG), as well as the psychophysiological measurement technique of self-reports of discomfort. As a second purpose, this paper examines whether a relationship exists between various job attitude factors and perceived discomfort scores.

McAtamney and Corlett (1993) examined the validity and reliability of RULA using a data-entry computer task as a model. They investigated the relationship between RULA's risk categories and psychophysiological measures. They used self-reports of perceived discomfort as a measure of physical risk for validity.

1.1. Electromyography (EMG)

To assess musculoskeletal stress associated with awkward working postures and the validity of ergonomic principles, EMG is often administered (National Institute for Occupational Safety and Health, 1992). EMG measures three things: temporal aspects (or phasic activation patterns), force, and fatigue. Oberg (1994) analysed the EMG signal, with respect to the root mean square (RMS) amplitude, of participants who performed two contractions of the right trapezius muscle by raising the right arm 90° of abduction with a 0-kg load for 5 min and a 2-kg load for 2 to 5 min. There was a statistically significant increase in RMS with increased load dose, as well as an increase in subjective fatigue scores. Another study by Dowler, Kappes, Fenaughty, and Pemberton (2001) examined muscle tension in the upper trapezius and forearm extensors during computer work in four different postures. These authors found no significant difference in the surface EMG recorded on the right versus the left side of the body. Meanwhile, a significantly lower recorded mean and normalized muscle activity was found in one of the four working postures. In the case of typing tasks involving dynamic contractions of the forearm muscles, a force production of about 20 to 30% of maximum voluntary contraction (MVC) would be expected (McLean, 1998).

This paper examines both the level of muscular activity, using the RMS of the raw EMG data, and how this level of activity changes across various working postures.

1.2. Perceived Discomfort

Bridger (1995) describes discomfort as resulting in an "urge to move" caused by a number of physical and physiological factors. Corlett and Bishop (1976) believe that an individual's level of discomfort is an indicator of the inadequacies of the match between the person and their work. The perceptions of postural pain were related to discomfort and would be linearly related to the duration of exposure to risk factors (Corlett & Bishop, 1976). Studies have shown a relationship between self-reports of discomfort and the level of muscle activation and load (Vasseljen & Westgaard, 1995; Wells et al., 1997).

1.3. Job Satisfaction

Job satisfaction can be defined as the pleasurable or positive emotional state resulting from the appraisal of one's job or job experience (Locke, 1976). Locke (1976) stated that job satisfaction results when the perception of the job fulfils one's important job values, providing that those values are congruent with one's needs. Typically, an individual will base their job satisfaction on both past and present work experiences. Hocking (1987) stated that studies have found job satisfaction to correlate with the presence of MSDs better than the ergonomic variables in their study. Smith (1997) demonstrated that highly monotonous computer work was associated with an increase in psychosomatic complaints and a decrease in job satisfaction. Floru, Cail, and Elias (1985) found that monotony, boredom, dissatisfaction, and lack of control over the workplace were common job stressors reported by operators. Job satisfaction has been shown in the literature to affect reports of body discomfort (Norman et al., 1998; Smith, 1997).

This paper also examines the relationship between job attitude scores (specific job satisfaction, general job satisfaction, work motivation, and job involvement) and perceived discomfort at the workplace.

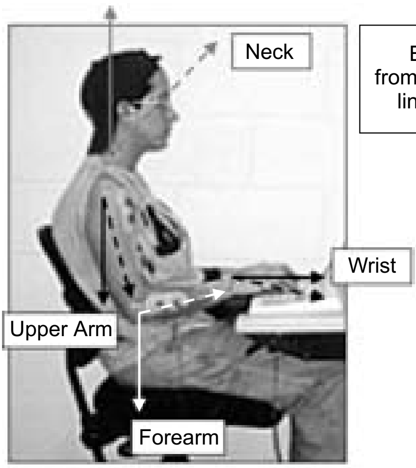
2. METHODS

Twenty participants with a mean age of 32 (range 21 to 55) each performed a 30-min typing task on a computer in three working postures based on RULA's scoring system (Figure 1), where posture 1 represented a low risk, posture 2 a medium risk, and posture 3 a high risk. For consistency, each posture was assigned a specific document for users to transcribe. For example, participants working in posture 1 always transcribed document A, whereas document B and C were dedicated to postures 2 and 3 respectively.

SCORE D (Neck, trunk, leg)								
		1	2	3	4	5	6	7+
SCORE C (Upper limb)	1	1	2	3	3	4	5	5
	2	2	2	3	4	4	5	5
	3	3	3	3	4	4	5	6
	4	3	3	3	4	5	6	6
	5	4	4	4	5	6	7	7
	6	4	4	5	6	6	7	7
	7	5	5	6	6	7	7	7
	8	5	5	6	7	7	7	7

Posture 1 = (low risk) Posture 2 = (medium risk) Posture 3 = (high risk)

Figure 1. RULA grand score and corresponding posture (amended from McAtamney & Corlett, 1993).



Each angle is measured from the solid line to the broken line for a positive direction.

	Posture 1	Posture 2	Posture 3
Neck	0–10	10–20	20+, twisted
Shoulder	0–20	20–45	45–90
Elbow	60–100	100+ or <60	100+ or <60
Wrist	0	±15	>±15

Figure 2. Definition of working postures.

Kinematic data were collected for the neck, shoulder, elbow, and wrist, to verify the participants' tested postures against RULA's defined posture system. These postures are defined in Figure 2.

The trunk and lower limb postures remained constant across all three tested postures. Six quasi-random samples of EMG were collected over each 30-min testing condition for the upper trapezius, anterior deltoid, biceps brachii, and forearm extensors. The raw EMG data were corrected for bias within a Microsoft Excel spreadsheet for further data processing. The root mean square (RMS) values were calculated for each of the six 1-s samples (1024 raw data). These six RMS values were then averaged to yield a mean RMS value for each muscle tested. The mean RMS values were then corrected for gain and the final mean RMS values in millivolts were used for statistical analysis.

The body discomfort survey (BDS) was modified from the method developed by Corlett and Bishop (1976) by including the addition of the left and right sides of the body. Participants were asked to rate their perceived level of discomfort based on a Likert scale of 0 to 7, where 0 represented *no discomfort* and 7 represented *extreme discomfort*. Discomfort was described to participants as any sensation of discomfort experienced, which may include pain, tingling, limited range of motion, weakness, and "pins and needles." Levels of perceived discomfort were collected for every pre- and post-testing condition. The difference between these perceived discomfort scores for each body part were summed to yield a total delta body discomfort score. The total delta body discomfort score was used for statistical analysis.

A Job Attitude Questionnaire (JAQ) was administered to all participants at their workplace, one day prior to the testing sessions, along with a BDS. Participants were asked to complete the questionnaire while working at their workstation around midmorning. The JAQ used a Likert scale and measured four factors: specific job satisfaction, general job satisfaction, job involvement, and work motivation. The participants were ranked based on a total Job Attitude score that was calculated from the sum of each factor score. The on-site BDS was used to rank each subject. These rankings were correlated with the rankings of participants in the JAQ. The reason for using a JAQ was twofold: (a) this study hoped to gain practical experience using such a tool; and (b) this study anticipated that these results might be hypothesis generating.

The participant's performance was also evaluated over the testing period by using the word count feature on the word processing software to determine the total number of words entered in 30 min. The total number of words typed was tabulated at the end of each 30-min testing condition and was used for statistical analysis.

During testing, participants were instructed to remain seated throughout the testing period while keeping their back against the chair's backrest. The laboratory floor was marked for the appropriate chair position so that participants would not move their chair. Participants were given a 30-min rest period between the three testing conditions. The reference material was standardized for each testing condition.

3. RESULTS

A multi-way repeated measures ANOVA was used to analyse the EMG (RMS) data (Table 1), whereas a one-way repeated measures ANOVA was used for perceived discomfort and performance (Table 2 and 3 respectively). In terms of the physiological measures, the only statistically significant effect was due to the duration of exposure for the forearm extensor muscles. A statistically significant difference was found in perceived discomfort from posture 1 to posture 3, however, no difference was found between postures 1 and 2, and between 2 and 3. A statistically significant difference was found in performance from posture 1 to 3, as well as posture 2 and 3, but not between postures 1 and 2.

TABLE 1. EMG (RMS) Descriptive Statistics (*N* = 20, in millivolts)

	Upper Trapezius			Anterior Deltoid		
	Posture 1	Posture 2	Posture 3	Posture 1	Posture 2	Posture 3
M	0.0283	0.0500	0.0293	0.0334	0.0420	0.0315
SD	0.0185	0.0505	0.0206	0.0508	0.0436	0.0226

	Biceps Brachii			Forearm Extensor		
	Posture 1	Posture 2	Posture 3	Posture 1	Posture 2	Posture 3
M	0.0305	0.0317	0.0226	0.1321	0.1423	0.1335
SD	0.0402	0.0569	0.0270	0.0523	0.0557	0.0695

The ANOVA and the Tukey HSD post hoc test revealed that there were no significant differences in the upper trapezius (F = 2.03, df 2/34, p < .15), anterior deltoid (F = 0.48, df 2/38, p < .62), biceps brachii (F = 0.37, df 2/38, p < .69), and forearm extensors (F = 0.35, df 2/38, p < .70) across the three working postures.

TABLE 2. Delta Body Discomfort Scores Descriptive Statistics (*N* = 20)

	Posture 1	Posture 2	Posture 3
M	0	5	7
SD	3	6	6

The ANOVA test demonstrated a significant difference in perceived discomfort (F = 16.01, *df* 2/38, $p < .00$) across the three working postures. The Tukey HSD post hoc test revealed that there was no significant difference in perceived discomfort between posture 2 and posture 3 ($p = .12$).

TABLE 3. Performance (Word Count) Scores Descriptive Statistics (*N* = 20)

	Posture 1	Posture 2	Posture 3
M	901	906	777
SD	368	368	304

The one-way repeated measures ANOVA demonstrated a significant difference in word count (F = 26.50, *df* 2/38, $p < .00$) across the three working postures. The Tukey HSD post hoc test revealed that there was no significant difference between posture 1 and 2 ($p = .97$).

Each subject was ranked in ascending order based on their total score calculated from the on-site BDS. Subjects were then ranked in descending order based on the total score calculated from the on-site Job Attitude Questionnaire (JAQ). The Pearson product moment correlation was performed on the data and resulted in a coefficient of $r = –0.08$.

4. DISCUSSION

The conventional physiological measurement technique of EMG (RMS) did not produce a significant difference whereas the psychophysiological measure of perceived discomfort resulted in a statistically significant difference. This resultant contradiction may be explained in three ways: (a) there is no physiological difference in the body's state across the three tested postures; (b) the physiological measure used here in this study was not an effective means for measuring physiological changes while performing computer tasks in the three tested postures; or (c) the statistical power was too low to demonstrate a statistically significant difference.

Although there was no statistically significant difference in EMG (RMS) across the three working postures, EMG should not be discarded. Instead, it is recommended that the EMG processing techniques be improved for future research. Upon closer examination of the results, it was noted that the variance is high relative to the means. Therefore, any differences across working postures would be difficult to detect. It is possible that the six samples of raw EMG data collected over each 30-min testing period were not representative of the muscle activation patterns.

Non-task related movements were observed by the examiner and were permitted in the testing conditions in order to recreate an applied situation. As some participants became uncomfortable, they would shift their weight, scratch their face, or stretch their arms in order to relieve their experienced strain. These movements may have contributed to the high variance. These subtle postural shifts will cause changes in muscle lengths and tensions thereby significantly impacting upon the EMG recording. Studies have shown that frequencies of postural shifts (non-task related movements) increase with the development of discomfort and fatigue (Karwowski, Eberts, Salvendy, & Noland, 1994; Liao & Drury, 2000).

A statistically significant difference was found in perceived discomfort from posture 1 to posture 3, however, no difference was found between postures 1 and 2, and between 2 and 3. RULA does not use equal joint angle ranges when defining the rating scores for each body part. For example, the neck will receive a score of 1 if the neck is in flexion from 0 to 10°, meanwhile a score of 3 is given for any neck angle greater than 20° flexion. The differences in joint angles between posture 1 and 2 may be too small and therefore result in the non-significant difference with respect to perceived discomfort results.

This study did not find a relationship between job satisfaction and perceived discomfort while participants were working at their workplace. These results contradict the results of other studies (Smith, 1997), which have shown that highly monotonous computer work was associated with increased psychosomatic complaints and decreased job satisfaction. Hocking (1987) states that previous studies found job satisfaction to correlate with the presence of MSDs better than the ergonomic variables used in their studies. It should be noted that the participants for this study did not have any known MSDs and were volunteers, and therefore were more likely to be motivated individuals with positive affectivity. The prevalence rate among self-reports of discomfort may be attributed to negative affectivity as described by Burke, Bried, and George (1993). Individuals with a high level of negative affectivity will focus on the negative aspects of their work environment, whereas individuals with positive affectivity will not.

There was a significant difference in the number of words typed across the three postures where the overall mean words typed were higher for postures 1 and 2 than for posture 3. This study cannot assume a cause and effect relationship on performance and working postures, because participants noted that the reference material for posture 3 was more technical in nature than that for postures 1 and 2. Also, the Tukey HSD post hoc test revealed a non-significant relationship between the mean word count of postures 1 and 2. The difference in text difficulty for posture 3 versus 1 and 2, may explain the fewer words typed in posture 3.

5. CONCLUSION

It is difficult to calculate a grand score level of risk that a task or workstation may place on an individual when we are still unable to determine with any degree of certainty the risk factors, combinations of these risk factors, and the number of risk factors that lead to the development of MSDs. The perceived discomfort results suggest that RULA's scoring system may be too general in nature to differentiate various levels of risk (low, moderate, and high) in its application to computer workstations. However, the perceived discomfort results demonstrated that RULA was able to identify high-risk postures. The next question we need to ask is, does perceived discomfort result in tissue damage, or does tissue damage yield discomfort?

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