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LUBA: an assessment technique for postural loading on the upper body based on joint motion discomfort and maximum holding time

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Abstract

This paper presents a technique for postural loading on the upper body assessment (LUBA). The proposed method is based on the new experimental data for composite index of perceived discomfort (ratio values) for a set of joint motions, including the hand, arm, neck and back, and the corresponding maximum holding times in static postures. Twenty male subjects participated in the experiment designed to measure perceived joint discomforts. The free modulus technique of the magnitude estimation method was employed to obtain subjects' discomforts for varying joint motions. The developed postural classification scheme was based on the angular deviation levels from the neutral position for each joint motion. These were divided into groups with the same degree of discomforts based on the statistical analysis. Each group was assigned a numerical discomfort score relative to the perceived discomfort value of elbow flexion, which exhibited the lowest level among all joint motions investigated in this study, and, therefore, was set as a reference point. The criteria for evaluating stresses of working postures were proposed based on the four distinct action categories, in order to enable practitioners to apply appropriate corrective actions. The proposed scheme can be used for evaluating and redesigning static working postures in industry.

Keywords: Postural loading; Upper body; Assessment technique; Joint discomfort

1. Introduction

Injuries and illness due to muscle, joint, and bone disorders from physical jobs account for more than 34% of all injuries that results in lost workdays, costing employers $15–$20 billion a year in worker compensation charges (OSHA, 1999). The relationship between awkward working postures and the risk of musculoskeletal disorders has been widely studied in the past. For example, van Wely (1969) discussed the relation between inadequate work postures and probable sites of pain, and Armstrong et al. (1993) reported a comprehensive review of epidemiological studies examining the relationship between work postures and musculoskeletal disorders. Heinsalmi (1986) and Burdorf et al. (1991) pointed out that a significant relationship was found between poor working postures and musculoskeletal-related lost workdays or low-back disorders. Bhatnager et al. (1985) indicated that a working posture affects postural discomfort and inspection performance for printed board reproductions.

Awkward, extreme, and repetitive postures can increase the risk of musculoskeletal disorders. Therefore, cost effective quantification of the magnitude for physical exposure to poor working postures is important and needed, if the potential for injury as a result of postures is to be reduced (Andrew et al., 1998). Since development of the Posturegram, a technique for numerically defining a posture proposed by Priel (1974), various postural classification methods have been developed to identify and quantify postural stress during work. These schemes can be classified into two basic categories depending upon the methods used for quantifying postural stresses: instrument-based and observational techniques. The latter is more widespread in industry, because it does not interfere with the worker during observations, and does not require use of expensive equipment for estimating the angular deviation of a body from the neutral position

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(Genaidy et al., 1994). The instrument-based method using bioinstrumentation such as electromyography has been rarely used as a major tool for quantifying postural stresses in industry, because it is expensive, obtrusive and limited due to the nature of the production process in industrial sites. Most postural classification schemes developed are the observation methods. These include the posture targeting (Corlett et al., 1979), OWAS (Karhu et al., 1977), PATH (Buchholz et al., 1996), and RULA (McAtamney and Corlett, 1993), etc.

Depending upon the grouping methods for joint motions involved in a classified posture, Genaidy et al. (1994) categorized the postural classification approaches used in observational techniques into: macropostural, micropostural, and postural-work activity classifications. The macropostural classification groups more than one non-neutral posture around a joint into one category, while the macropostural classification is more detailed than the previous method. The postural-work activity classification combines postures and work activities (Genaidy et al., 1994).

2. Objectives

Although the existing methods have proved useful for quantification of postural stresses in the field studies, and contributed to preventing work-related musculoskeletal disorders, they have many disadvantages. First, many of the observational classification schemes are not based on experimental data. Second, the existing methods have been developed for specific application purposes, and, consequently, are not generic in many respects. Third, many methods deal with only a few representative joint motions, as they focus on specific joint motions frequently linked to musculoskeletal disorders. Another problem is that only a few schemes (including OWAS and RULA) utilize specific evaluation criteria for the classified postures, which provide information on any corrective actions to be undertaken for reducing postural burden at work. In addition, the evaluation criteria provided by RULA and OWAS were not based on experimental results, but rather relied on the rankings provided by ergonomists and occupational physiotherapists using the biomechanical and muscle function criteria (McAtamney and Corlett, 1993), or the subjective rankings provided by the experienced steel workers (Karhu et al., 1977), respectively.

This paper presents a new technique for postural loading on the upper body assessment (LUBA). The method is based on new experimental data for the composite index of perceived discomfort, expressed as numerical ratio scores for a set of joint motions, including the hand, arm, neck and back, and the corresponding maximum holding times in static postures.

3. Methods

3.1. Subjects

Twenty male subjects with no history of musculoskeletal disorders volunteered for participation in the experiment. Their physical characteristics were as follows: (1) age—25.2 ± 2.6 years; (2) stature—172.1 ± 5.7 cm; and (3) body weight—66.8 ± 6.8 kg.

3.2. Rating method and experimental design

Perceived joint discomforts for a given set of postures were obtained using the numerical estimation and free modulus method of the magnitude estimation, one of the psychophysical scaling methods (Gescheider, 1985; Han et al., 1998; Lodge, 1981). The magnitude estimation method requires an observer to make direct numerical estimations of the sensory magnitudes produced by various stimuli. The method has an advantage that it produces quantitative data with the characteristics of the ratio scale, which can be subject to various statistical analyses. On the contrary, the traditional category scaling method provides only qualitative information such as frequency distribution of subjective feelings, although it has been widely used in the past, and is easy to administer. Since this study aimed to quantify perceived discomforts for different joint motions, which would be subject to varying quantitative (statistical) analysis, and since the magnitude scales are almost invariably found to be superior in providing quantitative information about the intensity of people's judgments, the magnitude estimation method was employed for data collection purposes. In addition, the free modulus method was adopted among three modulus methods of the magnitude estimation: modulus method, free modulus method, and absolute method. The subjects used their own standards without any modulus for comparison, since a standard stimulus causes the potential bias effects for the response. According to Gescheider (1985), it is better to permit the subjects to choose their own modulus rather than to designate one for them.

Perceived discomforts were gathered for varying postures of five joints in the upper body (Table 1), which included almost every possible joint motion occurring in the sitting and standing postures. In the seated position, a chair with backrest perpendicular to the seat pan and with no arm rests, was used. In the standing posture, the subjects were asked to stand on the board with a height elevation of 20 cm. Perceived discomforts were measured at five levels of range of joint motion (ROM) in each motion: 0% (neutral), 25, 50, 75, and 100% of ROM, respectively.

It should be noted that the ratings of joint discomfort of upper body were based on short time exposure conditions. Such conditions often occur in many

Table 1
Joint motions measured in this study

Joint motion\Joint	Posture	
	Sitting	Standing
Wrist	Flexion	Flexion
	Extension	Extension
	Radial deviation	Radial deviation
	Ulnar deviation	Ulnar deviation
Elbow	Flexion	Flexion
	Supination	Supination
	Pronation	Pronation
Shoulder	Flexion	Flexion
	Extension	Extension
	Adduction	Adduction
	Abduction	Abduction
	Medial rotation	Medial rotation
	Lateral rotation	Lateral rotation
Neck	Flexion	Flexion
	Extension	Extension
	Rotation	Rotation
	Lateral bending	Lateral bending
Lower back	Flexion	Flexion
	Rotation	Extension
	[a]	Rotation
	Lateral bending	Lateral bending

[a]Not measured.

contemporary jobs in the office environment, construction industry, and agriculture (NIOSH, 1997). Previous studies also used the 60 s interval for evaluating of joint motion discomforts (Genaidy and Karwowski, 1993; Genaidy et al., 1995).

3.3. Experimental procedure

Prior to experiment, subjects were informed of the purpose and procedures of the experiment through a 30-min training session, and an informed consent was obtained. Anthropometric dimensions including stature and body weight were also measured.

The experiment consisted of three steps: (1) administrating a calibration test; (2) determining the joints' ROMs; and (3) measuring perceived discomforts. In the calibration test, the subjects were asked to assign numerical values to 10 randomly presented line length stimuli with a 100 : 1 range. This test allowed to verify that the relationship between logarithmically transformed response values and line length stimuli was linear, i.e., the regression coefficient between the two transformed variables was 1.0 ($\alpha = 0.05$). It is noted that the exponent of the power function relating subjective magnitude to line length stimuli is known to be 1.0. Those subjects who were unable to properly perform the magnitude estimation test were screened out of the experiment.

The ROMs for the joint motions shown in Table 1 were measured for the subjects who passed the calibration test. The definitions of joint motions were taken from several studies. Definitions for the wrist, elbow, and neck motions were based on Murrell (1969); those of the shoulder motions were adopted from Chaffin and Andersson (1991); Hsiao and Keyserling (1991); Kroemer et al. (1994); and those for the back movements from Hsiao and Keyserling (1991); Kee (1997).

Finally, the subjects were asked to rate their perceived discomforts for a given set of postures using the free modulus method of the magnitude estimation. The subjects were instructed to assume a series of postures according to the experimental design one at a time, and to assign a number to every posture, so that their impression of that number matched their impression of the intensity of perceived discomfort for a given posture. This was done during a 1-min rest period after the posture was sustained for 1 min. No reference numbers and verbal anchors (as it is practiced in the traditional category scaling method) were given to the subjects, so that they could assign a number to intensity of perceived discomfort using their own scale.

All experimental treatments were randomly presented to each of the 20 subjects. Each subject attended five consecutive sessions on separate days. Each experimental session was composed of 5-min warm-up using the (Aerometer, Lafayette Co., 1987), 10 practice trials and 24 experimental trials, and each session lasted about 70–80 min. During the warm-up period, the subjects were asked to ride a stationary bicycle at their own pace for 5 min.

4. Results

4.1. Normalization

Since the free modulus method of the magnitude estimation was used to obtain the subjects' perceived discomfort ratings, each subject used different reference points to represent the intensity of his own discomfort. Therefore, in order to compare the raw data across all subjects, and to use them in further analysis, the normalization method proposed by Hwang and Yoon (1981) was applied to all ratings. The formula for normalization is as follows:

$$\text{Normalized discomfort}_{ijk} = \frac{\text{raw data}_{ijk} - \text{min discomfort}_k}{\text{max discomfort}_k - \text{min discomfort}_k} \times 100,$$

where i is the ith level of motion; j is the jth joint motion; k is the kth subject; raw data$_{ijk}$ is the discomfort at the ith level of the jth joint motion in the kth subject; max discomfort$_k$ is the maximum discomfort in the kth subject; min discomfort$_k$ is the minimum discomfort in the kth subject; normalized discomfort$_{ijk}$ is the normalized discomfort at the ith level of the jth joint motion in the kth subject.

4.2. Relative discomfort scores by joint motions

First, five angular deviation levels from the neutral position in each joint motion were divided into groups with the same degree of normalization discomforts through the Tukey range test of SAS ($\alpha = 0.05$). To be practical, the observational techniques should be simple and easy to learn and use, time-efficient, reliable, non-invasive, and should be easily recognizable according to the overall range of movements (Juul-Kristensen et al., 1997; Keyserling, 1986).

In this study, the angular intervals in each group produced by the statistical analysis were modified to intervals with general angular values that can be visually recognized, taking into account the results of existing postural classification schemes including Armstrong et al. (1982); Kilbom et al. (1986); Keyserling (1986, 1990); Genaidy et al. (1993), PEO (Juul-Kristensen et al., 1997), VIRA (Juul-Kristensen et al., 1997), TRAC (Van der Beek et al., 1992), OWAS (Karhu et al., 1977), RULA (McAtamney and Corlett, 1993), and PATH (Buchholz et al., 1996), etc. For example, the statistical analysis of back rotation in the sitting posture resulted in four joint motion classes: 0, 25, 50–75, and 100% of ROM. The upper bound of the third class, i.e., 75% of ROM, was 51°, but it was modified to 45° which is easier to identify.

Next, each joint motion class was assigned a numerical relative discomfort score on the basis of normalization discomfort value for the neutral position of elbow flexion, which was the least stressful of all the joint motions investigated. A relative discomfort score of 1.0 was assigned to the neutral position of elbow flexion, with a higher number indicating that a given joint motion class is more stressful. The relative discomfort score is the ratio scale that could be applied to four arithmetic rules such as addition, subtraction, multiplication, and division. In other words, the back flexion of $> 60°$ with the relative discomfort score of 10 has 10 times the discomfort magnitude of the elbow flexion of 0–45°, the relative discomfort score of which is 1.0. The developed

Table 2
Postural classification scheme for the wrist

Posture and discomfort score\Joint motions	Sitting posture		Standing posture	
	Class	Relative discomfort score	Class	Relative discomfort score
Flexion	0–20°	1	0–20°	1
	20–60°	2	20–60°	2
	> 60°	5	> 60°	5
Extension	0–20°	1	0–20°	1
	20–45°	2	20–45°	2
	> 45°	7	> 45°	7
Radial deviation	0–10°	1	0–10°	1
	10–30°	3	10–30°	3
	> 30°	7	> 30°	7
Ulnar deviation	0–10°	1	0–10°	1
	10–20°	3	10–20°	3
	> 20°	6	> 20°	6

Table 3
Postural classification scheme for the elbow

Posture and discomfort score\Joint motions	Sitting posture		Standing posture	
	Class	Relative discomfort score	Class	Relative discomfort score
Flexion	0–45°	1	0–45°	1
	45–120°	2	45–120°	3
	> 120°	5	> 120°	5
Pronation	0–70°	2	0–70°	2
	> 70°	7	> 70°	7
Supination	0–90°	2	0–90°	2
	> 90°	7	> 90°	7

Table 4
Postural classification scheme for the shoulder

Posture and discomfort score\Joint motions	Sitting posture		Standing posture	
	Class	Relative discomfort score	Class	Relative discomfort score
Flexion	0–45°	1	0–45°	1
	45–90°	3	45–90°	3
	90–150°	6	90–150°	6
	> 150°	11	> 150°	11
Extension	0–20°	1	0–20°	1
	20–45°	4	20–45°	3
	45–60°	9	45–60°	6
	> 60°	13	> 60°	10
Adduction	0–10°	1	0–10°	1
	10–30°	2	10–30	2
	> 30°	8	> 30°	8
Abduction	0–30°	1	0–30°	1
	30–90°	3	30–90°	3
	> 90°	10	> 90	7
Medial rotation	0–30°	1	0–30°	1
	30–90°	2	30–90°	2
	> 90°	7	> 90°	5
Lateral rotation	0–10°	1	0–10°	1
	10–30°	3	10–30°	2
	> 30°	7	> 30°	5

Table 5
Postural classification scheme for the neck

Posture and discomfort score\Joint motions	Sitting posture		Standing posture	
	Class	Relative discomfort score	Class	Relative discomfort score
Flexion	0–20°	1	0–20°	1
	20–45°	3	20–45°	3
	> 45°	5	> 45°	5
Extension	0–30°	1	0–30°	1
	30–60°	6	30–60°	4
	> 60°	12	> 60°	9
Lateral bending	0–30°	1	0–30°	1
	30–45°	3	30–45	2
	> 45°	10	> 45°	7
Ulnar deviation	0–30°	1	0–30°	1
	30–60°	2	30–60°	2
	> 60°	8‘	> 60°	8

relative discomfort score scheme is presented in Tables 2–6, which are classified by the joints involved in motions.

As shown in Tables 2–6, the relative discomfort scores are almost identical for both sitting and standing postures, and increase drastically when the joints approach the limit of their range of motion. The results also showed that back movements were perceived as more stressful than any other joint motion. Specifically, the back extension of $> 30°$ (with a relative discomfort score of 15) in the standing posture was the most stressful of all the joint motions examined.

4.3. Posture evaluation procedures

Procedures used for application of the postural classification scheme consisted of five steps: First, the operator was videotaped in order to record working postures during several work cycles. This was done for selecting of the tasks and postures to be assessed in the next step. Typically, a camera should be positioned at an angle to the operator so that three-dimensional working postures can be identified during playback. Several working cycles should be recorded because postures can vary from cycle to cycle depending upon the nature and demands of the

Table 6
Postural classification scheme for the back

Posture and discomfort score\Joint motions	Sitting posture		Standing posture	
	Class	Relative discomfort score	Class	Relative discomfort score
Flexion	0–20°	1	0–30°	1
	20–60°	3	30–60°	3
	> 60°	10	60–90°	6
			> 90°	12
Extension	[a]	[a]	0–10°	1
			10–20°	4
			20–30°	8
			> 30°	15
Lateral bending	0–10°	1	0–10°	1
	10–20°	3	10–20°	4
	20–30°	9	20–30°	9
	> 30°	13	> 30°	13
Rotation	0–20°	1	0–20°	1
	20–30°	2	20–60°	3
	30–45°	7	> 60°	10
	> 45°	11		

[a]Not measured.

job (Keyserling, 1986), and many of the unusual conditions which may constitute main hazards should be included (Kemmlert, 1995). Second, target postures of the recorded job were chosen for assessment, based on the posture holding time or possible postural stresses. The postures to be assessed may be those that are held for the greatest amount of the work cycle, or those that the worker itself (or the observer) considers as stressful to the musculoskeletal system. Third, each joint motion observed in the selected postures is assigned a relative discomfort score according to the above classification scheme.

Fig. 1 makes it easy and fast for the posture analysts to classify working postures, where they just tick the corresponding item for each joint motion. After completion of posture classification, the postural load for the selected posture can be obtained by summing up the respective discomfort score values ticked in Fig. 1. Fourth, the following equation is used to calculate the postural load index for joint motions deviated from their neutral positions in the chosen postures, i.e., for joint motions having relative discomfort scores of 2 or more. The postural load index is calculated for the left or right arm/hand, the neck, and back motions. Only the right or left arm/hand is assessed at a time when calculating postural load index. Finally, based on the postural load index, the posture is evaluated using the criterion discussed in the following section in terms of whether the posture is acceptable or any correction actions are needed:

$$\text{Postural load index} = \sum_{j=1}^{n} \sum_{i=1}^{mj} Sij,$$

where i is the ith joint motion, j is the jth joint; n is the number of joints involved, m_j is the number of joint motions studied in the jth joint, S_{ij} is the relative discomfort score of the ith joint motion in the jth joint, (Here, $S_{ij} = 0$ if a corresponding relative discomfort score is 1.0).

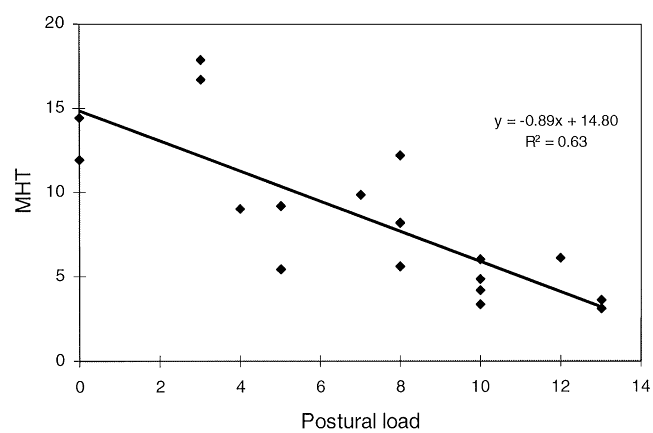

Fig. 1. The relationship between postural load index and MHT.

4.4. Categorization of classified postures

After each classified posture was assigned a relative discomfort score according to the above classification method, a criterion is needed to evaluate the level of corrective actions. In this study, such evaluation criterion was developed on the basis of the maximum holding time (MHT), as discussed by Miedema et al. (1997), in which the MHTs of 19 standing postures from seven different experimental studies were analyzed.

Miedema et al. (1997) classified working postures into three categories, depending on the mean value of

Table 7
MHT and postural load index

Posture categories	MHT (min)	Postural load index
Comfortable postures	37.0	3
(MHT > 10 min)	18.0	3
	17.0	3
	14.0	0
	12.0	8
	12.0	0
Moderate postures	10.0	7
(5 m ⩽ MHT ⩽ 10 min)	9.0	5
	9.0	4
	8.0	8
	6.0	12
	6.0	10
	5.5	8
	5.5	5
Uncomfortable postures	5.0	10
(MHT < 5 min)	4.0	10
	3.5	13
	3.3	10
	3.0	13

the MHT, as follows: (1) comfortable; (2) moderate; and (3) uncomfortable postures. For the purpose of the current study, postural load indices for 18 postures were calculated using the postural classification scheme as shown in Tables 2–6 and summarized with the corresponding MHT values in Table 7. It should be noted that a posture with the MHT value of 37.2 min was excluded from the analysis because it was thought to be an outlier.

The relationship between the MHT and postural load index defined in the present study for the 18 postures is illustrated in Fig. 2. It was shown that the MHT and postural load index were negatively correlated, with the correlation coefficient of –0.79 ($p < 0.000$). This relationship was well fitted with a linear model ($R^2 = 62.7\%$). This implies that the postural load index well reflects stresses related to working postures.

Four action categories were presented based on the above analysis, among which the first three categories were the same as Miedema et al. (1997) classification of postures. For example, in category I, a boundary value of five in the postural load index was approximately obtained by inversely calculating the independent variable (i.e., postural-load index) for the dependent variable having the MHT of 10 min, which corresponded to the limit value for comfortable posture in Miedema et al. (1997) classification, using the regression equation in Fig. 2. The proposed four action categories are as follows:

Category I: Postures with the MHT of more than 10 min, and postural load index of five or less. This category of postures is acceptable, except in special situations such as repeating and sustaining them for long periods of time, etc. No corrective actions are needed.

Category II: Postures with the MHT of 5–10 min, and postural load index from 5 to 10. This category of postures requires further investigation and corrective changes during the next regular check, but immediate intervention is not needed.

Category III: Postures with the MHT of five or less minutes, and postural load index from 10 to 15. This category of postures requires corrective action through redesigning workplaces or working methods soon.

Category IV: Postures with the MHT of less than 2 min, and postural load index of 15 or more. This category of postures requires immediate consideration and corrective action.

The above action categories are illustrated in Fig. 3.

5. Discussion

The results of the present study showed that the relative discomfort scores were different depending upon joint motions studied, and the MHT by Miedema et al (1997) and postural load index defined in this study were negatively correlated. These findings are in agreement with the previous study (Boussenna et al., 1982), which reported that discomforts in body parts were significantly affected by posture, and that the posture holding times were significantly negatively correlated with posture or postural loading.

The newly developed postural classification scheme was based on subjective perceived discomforts, which was justified by the following facts: (1) Corlett and Bishop (1976) and Corlett and Manenica (1980) pointed out that the limit to the posture holding time was the acceptable level of discomfort, and that the discomforts were a valid measure of postural load; and (2) Boussenna et al. (1982) indicated that body-part discomfort was related to more objective measure, for example, the torque at the joint just distal to the site of discomfort.

Although the new postural classification scheme overcame disadvantages of some existing postural classification schemes to a great extent (as discussed in Objectives), there are also limitations. The main limitations are as follows: (1) only the posture held for 60 s was investigated as an independent variable among varying factors such as external load (force), repetitiveness (frequency) and duration, which are known to affect the perceived discomfort levels and mechanical exposure to musculoskeletal injury (Juul-Kristensen et al., 1997; Winkel and Mathiassen, 1994); (2) perceived discomforts were obtained only on static joint motions held for 60 s rather than on dynamic motions, which are more frequently found in real situations; (3) joint postures and motions

Department: Task: Operator:
Analyst name: Date:

Joint	Motion	Class	Score		Motion	Class	Score	
Wrist	Flexion	0-20°	1	___	Extension	0-20°	1	___
		20-60°	4	___		20-45°	5	___
		>60°	9	___		>45°	11	___
	Radial deviation	0-10°	1	___	Ulnar deviation	0-10°	1	___
		10-30°	5	___		10-20°	5	___
		>30°	10	___		>20°	9	___
Elbow	Flexion	0-45°	1	___	Supination	0-90°	3	___
		45-120°	3	___		>90°	9	___
		>120°	7	___				
	Pronation deviation	0-70°	3	___				
		>70°	9	___				
Shoulder	Flexion	0-45°	1	___	Extension	0-20°	1	___
		45-90°	5	___		20-45°	7	___
		90-150°	9	___		45-60°	12	___
		>150°	14	___		>60°	16	___
	Adduction	0-10°	1	___	Abduction	0-30°	1	___
		10-30°	4	___		30-90°	6	___
		>30°	11	___		>90°	13	___
	Medial rotation	0-30°	1	___	Lateral rotation	0-10°	1	___
		30-90°	4	___		10-30°	5	___
		>90°	10	___		>30°	10	___
Neck	Flexion	0-20°	1	___	Extension	0-30°	1	___
		20-45°	5	___		30-60°	9	___
		>45°	8	___		>60°	15	___
	Lateral bending	0-30°	1	___	Rotation	0-30°	1	___
		30-45°	5	___		30-60°	4	___
		>45°	13	___		>60°	11	___
Back	Flexion	0-20°	1	___	Extension	Not included		
		20-60°	6	___				
		>60°	13	___				
	Lateral bending	0-10°	1	___	Rotation	0-20°	1	___
		10-20°	5	___		20-30°	3	___
		20-30°	12	___		30-45°	7	___
		>30°	16	___		>45°	14	___
Postural load =								

Fig. 2. Checklist for evaluating postures.

were expressed using a single degree of freedom, even though a real posture is actually defined by combining multiple degrees of freedom; and (4) the experiment was conducted in the laboratory rather than in the industrial settings. Therefore, further research to resolve the above problems is needed.

Due to these limitations, caution is required when applying the developed postural classification scheme, especially to the jobs or tasks that have external load or long duration, or are highly repetitive, because the scheme was developed on the basis of subjective perceived discomforts without taking into consideration some relevant factors including external load, repetitiveness and duration, etc. Winkel and Westgaard (1992) showed through a review of 39 relevant studies that all these factors mentioned above are rarely considered simultaneously. It is recommended that the postural classification scheme be used as a preliminary tool in a comprehensive macro-ergonomic risk assessment to quickly evaluate several jobs and to rank their effects in terms of postural loading (Genaidy et al., 1994).

6. Conclusions

In this study, a technique for assessment of static postures (LUBA) was developed based on the new experimental data for perceived discomfort values for a set of joint motions, including the hand, arm, neck, and back, and the existing data for maximum holding times in static postures. Each postural class was assigned a relative discomfort score with the characteristics of the ratio scale relative to the perceived discomfort for the neutral position of elbow flexion. The ratio discomfort score makes it easy to quantitatively evaluate postural stresses for varying postures and to compare them across

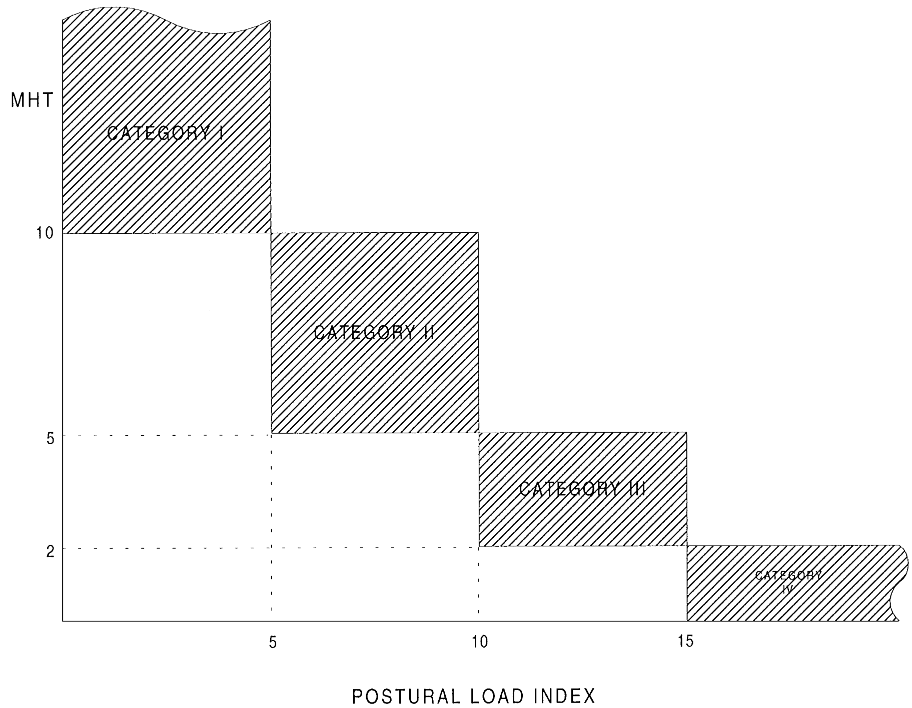

Fig. 3. Graphical representation of the four action categories.

different postures. In addition, an evaluation criterion for the classified postures enables practitioners of health and safety to decide on whether or not corrective actions are needed. It is expected that the postural classification scheme based on consideration of perceived discomfort and static holding times can be used as a tool for assessing postural stresses and preventing posture-related musculoskeletal disorders. Such expectation is justified in view of the fact that minimization of discomfort can contribute to reduction of the risk for musculoskeletal problems (Dul et al., 1994; Milner, 1985; Nag, 1991; Putz-Anderson and Galinsky, 1993; Zhang et al., 1996), and that body-part discomfort is related to the objective measures such as torque at the relevant joints (Boussenna et al., 1982).

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