A Comparison of Three Observational Techniques for Assessing Postural Loads in Industry

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This study aims to compare 3 observational techniques for assessing postural load, namely, OWAS, RULA, and REBA. The comparison was based on the evaluation results generated by the classification techniques using 301 working postures. All postures were sampled from the iron and steel, electronics, automotive, and chemical industries, and a general hospital. While only about 21% of the 301 postures were classified at the action category/level 3 or 4 by both OWAS and REBA, about 56% of the postures were classified into action level 3 or 4 by RULA. The inter-method reliability for postural load category between OWAS and RULA was just 29.2%, and the reliability between RULA and REBA was 48.2%. These results showed that compared to RULA, OWAS, and REBA generally underestimated postural loads for the analyzed postures, irrespective of industry, work type, and whether or not the body postures were in a balanced state.

observational technique   OWAS   RULA   REBA   musculoskeletal disorders

1. INTRODUCTION

Work-related musculoskeletal disorders (WMSDs) constitute an important occupational problem for both developed and developing countries, with rising costs of wage compensation and medical expenses, reduced productivity, and lower quality of life [1, 2]. In Korea, although the traditional occupational diseases such as hearing loss and organic material toxication have decreased, WMSDs, including low back injuries, increased by 250% in 2003, compared to those reported in 2002. Economic losses due to WMSDs in Korea are estimated to be about 1.3 trillion won (US $1 billion), which approximately amounts to 0.3% of the gross national product (GNP) [3].

In order to prevent WMSDs, major risk factors causing WMSDs should be quantitatively analyzed.

WMSDs are caused by multi-factorial interactions of various risk factors, which can be classified into three main groups: individual, psychosocial, and physical. Among the physical workload, body posture, repetitive and forceful activities, static muscle load, mechanical stress, vibration, and cold are known to be the most prevalent [3, 4, 5, 6, 7]. Since the relation between awkward postures and pain has been discussed by van Wely [8], several researchers have pointed out that poor working postures contribute to musculoskeletal problems in industry [9, 10, 11, 12].

Research techniques that have been proposed for quantifying the amount of discomfort and postural stress caused by different body postures can be divided into observational and instrument-based techniques. In the observational technique, the angular deviation of a body segment from

the neutral position is obtained using visual perception. In the instrument-based techniques, continuous recordings of a body posture are taken through a device attached to a person. Because of noninterference with job processes, low cost, and use ease, the observational techniques are more widely used in industry [13].

The observational techniques include OWAS [14], TRAC [15], PATH [16], RULA [17], REBA [18], LUBA [19], PLAS [20], etc. Of these techniques, OWAS, RULA, and REBA are widely used in Korea. A review of several observational techniques showed that they had been developed for different purposes, and consequently applied under a variety of workplace conditions [21]. Each technique has its own posture classification scheme, which is different from other techniques. This may result in assignment of different postural load scores for a given posture, depending upon particular techniques used. However, a comparison of these three techniques with respect to their performance and reliability has not been performed.

Since the time of publication of these techniques, research showed their usefulness for postural assessments of jobs in several occupational settings, including construction [22], agriculture [23, 24], a hammering task [25], nursing [26, 27], supermarket workers [11, 28], poultry industry [29], ship maintenance [30], a soft drinks distribution center [31], a metalworking firm [32], truck drivers [33], a carpet mending operation [34], etc.

The present study aims to compare representative observational techniques, namely, OWAS, RULA, and REBA, in terms of agreement in distribution of postural loading scores (coincidence rate) and inter-technique reliability, based on an analysis of 301 postures taken from varying industries.

1.1. OWAS

The OWAS technique (Ovako Working Posture Analysing System) was developed by a Fininish steel company of Ovako Oy [14]. The method is based on ratings of working postures taken in several divisions of one steel factory performed by 32 experienced steel workers and international ergonomists. OWAS identifies four work postures for the back, three for the arms, seven for the lower limbs, and three categories for the weight of load handles or amount of force used. The technique classifies combinations of these four categories by the degree of their impact on the musculoskeletal system for all posture combinations. The degrees of the assessed harmfulness of these posture–load combinations are grouped into four action categories, which indicate the urgency for the required workplace interventions [14, 24]:

- action category 1: normal postures, which do not need any special attention;
- action category 2: postures must be considered during the next regular check of working methods;
- action category 3: postures need consideration in the near future;
- action category 4: postures need immediate consideration.

1.2. RULA

The RULA technique (Rapid Upper Limb Assessment) was proposed to provide a quick assessment of the loading on the musculoskeletal system due to postures of the neck, trunk, and upper limbs, muscle function, and the external loads exerted. Based on the grand score of its coding system, four action levels, which indicate the level of intervention required to reduce the risks of injury due to physical loading on the worker, were suggested [17]:

- action level 1: posture is acceptable;
- action level 2: further investigation is needed and changes may be needed;
- action level 3: investigation and changes are required soon;
- action level 4: investigation and changes are required immediately.

1.3. REBA

The REBA technique (Rapid Entire Body Assessment) is a postural analysis system sensitive to musculoskeletal risks in a variety of tasks, especially for assessment of working

postures found in health care and other service industries. The posture classification system, which includes the upper arms, lower arms, wrist, trunk, neck, and legs, is based on body part diagrams. The method reflects the extent of external load/forces exerted, muscle activity caused by static, dynamic, rapid changing or unstable postures, and the coupling effect. Unlike OWAS and RULA, this technique provides five action levels for evaluating the level of corrective actions [18]:

- action level 0: corrective action including further assessment is not necessary;
- action level 1: corrective action including further assessment may be necessary;
- action level 2: corrective action including further assessment is necessary;
- action level 3: corrective action including further assessment is necessary soon;
- action level 4: corrective action including further assessment is necessary now.

2. METHODS AND PROCEDURES

2.1. Working Postures Used

A total of 301 working postures were sampled from various manufacturing industries including iron and steel (68 postures), electronics (46 postures), automotive (44 postures), and chemical industries (66 postures), and the service industry of a general hospital (77 postures). The manufacturing industries and the general hospital were selected, because (a) WMSDs in the manufacturing industries amounted to about

65 and 80% of the reported WMSDs in the USA and Korea, respectively [35, 36]; (b) the work of nurses in a hospital environment is often associated with a heavy physical workload and musculoskeletal disorders [26, 37]; and (c) the nursing profession ranks second after industrial work, where high physical workload is of concern [26]. The postures were sampled so that they covered varying work types such as lifting and seated tasks, and leg postures including balanced or unbalanced (Table 1). The selected postures were chosen from the working images recorded with a camcorder (Handycam, Sony), based on the extent of observed postural loading. When taking pictures of working postures, the camera was positioned at an angle to the operator so that three-dimensional working postures could be identified during playback. The selected postures used in this study were those that the field observers classified as stressful to the human musculoskeletal system.

2.2. Comparison Scheme

First, an ergonomist assessed the 301 postures by using three observational techniques, which resulted in three postural load scores for each posture by each of the applied techniques. The postures were reassessed after 3 weeks by the ergonomist. The intra-rater reliabilities for OWAS, RULA, and REBA were 95.0, 91.7, and 97.3%, respectively. OWAS and RULA classifies postural load for the urgency of corrective actions into four action categories or action levels, respectively, the meanings of which are almost the same. REBA groups postural loads into

TABLE 1. Distribution of Sampled Postures

Sampled Postures		Iron and Steel	Electronics	Automotive	Chemical	Hospital	Total
Work type	Lifting	19 (27.9)	22 (47.8)	7 (15.9)	27 (40.9)	14 (18.2)	89 (29.6)
	Seated task	0 (0.0)	0 (0.0)	6 (13.6)	2 (3.0)	5 (6.5)	13 (4.3)
	Others	49 (72.1)	24 (52.2)	31 (70.5)	37 (56.1)	58 (75.3)	199 (66.1)
Leg postures	Balanced	45 (66.2)	40 (87.0)	36 (81.8)	54 (81.8)	72 (93.5)	247 (82.1)
	Unbalanced	23 (33.8)	6 (13.0)	8 (18.2)	12 (18.2)	72 (93.5)	5 (6.5)
Total		68 (22.6)	46 (15.3)	44 (14.6)	66 (21.9)	77 (25.6)	301 (100)

Notes. The numbers in parentheses represent percentage values.

five action levels, which have slightly different meanings form the action categories/levels of OWAS/RULA. For effective comparison, the five action levels of REBA were regrouped into four categories with consideration of the meanings of action categories/levels for these three techniques. The new four action levels of REBA were as follows: action level 1 (originally action level 0), 2 (originally action level 1 and 2), 3 (originally action level 3) and 4 (originally action level 4).

Second, the analyzed postures were classified on the basis of industry, work type, and leg posture. According to work type, the postures were grouped into three categories: lifting, seated tasks, and other tasks. Other tasks were defined as all tasks except for lifting and seated tasks. Following the posture classification scheme of RULA for legs, the postures were also grouped into two categories, depending upon whether or not legs and feet were well supported and in an evenly balanced posture. Since OWAS and REBA divide leg postures into relatively more classes of seven or four, respectively, it is questioned whether or not RULA with only two classes of leg posture properly assesses postural loading, including unbalanced leg postures. To investigate this, a comparison by leg posture was also conducted. The distribution of postures by work type and leg postures was summarized in Table 1.

Finally, a comparison of the three techniques was conducted, based on postural loads at each action category level. The comparison was classified by industry, work type, and leg postures. All comparison results were statistically tested by the Wilcoxon sign test.

3. RESULTS

3.1. Comparisons by Industry

3.1.1. OWAS and RULA

Action categories/levels of OWAS/RULA for 301 postures by industry are illustrated in Figure 1, which shows frequencies of OWAS action categories against RULA action levels. The Wilcoxon sign test showed that compared to

RULA, OWAS generally underestimated postural loads for the varying postures, irrespective of industry ($p < .0001$). This underestimation of OWAS was more manifest in the electronics industry and the general hospital environment. One posture for inspection in the automotive sector and nine postures in the chemical industries (four lifting and five processing/assembly tasks) were significantly underestimated. These were assessed with action level 4 by RULA, and action category 1 by OWAS, respectively. However, there were no postures that OWAS overestimated, except for one and five postures for maintenance in the automotive and iron and steel industries, respectively. The six postures were assessed with action category 3 by OWAS, but with action level 2 by RULA. The inter-technique reliabilities ranged from 16.8% for the general hospital to 47.1% in the iron and steel industry.

3.1.2. OWAS and REBA

Compared to REBA, OWAS appears to slightly underestimate the risk levels associated with working postures ($p < .0001$) (Figure 2). Many postures assessed with action level 2 by REBA were evaluated with action category 1 by OWAS, especially in the electronics and chemical industries, and the general hospital. Significance difference was not found in the iron and steel, and automotive industries. The inter-technique reliabilities reached between 39.4 and 70.6% according to type of industry, the minimum and maximum of which were found in the chemical, and the iron and steel industries, respectively.

3.1.3. RULA and REBA

Like OWAS, REBA showed a tendency to underestimate postural loads for 301 postures used in this study regardless of industry, compared with the results of evaluations by RULA ($p < .0001$) (Figure 3). The higher the postural load levels were, the lower the coincidence rate of assessment results between the two methods were observed. For example, the coincidence rate for postures with low postural loads of action level 1 or 2 by RULA (94.7%) was much higher than that for postures with high
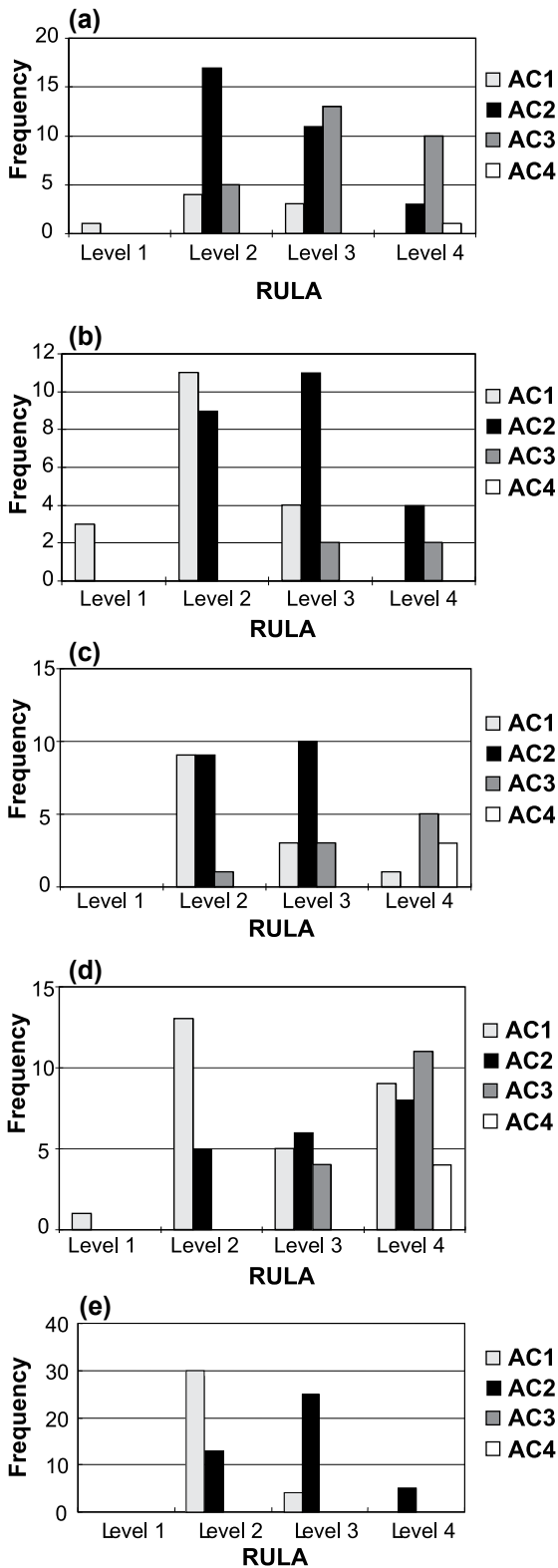
Figure 1. OWAS action categories (AC) and RULA action levels by industry: (a) iron and steel industry, (b) electronics industry, (c) automotive industry, (d) chemical industry, (e) general hospital. *Notes.* OWAS—Ovako Working Posture Analysing System, RULA—Rapid Upper Limb Assessment.
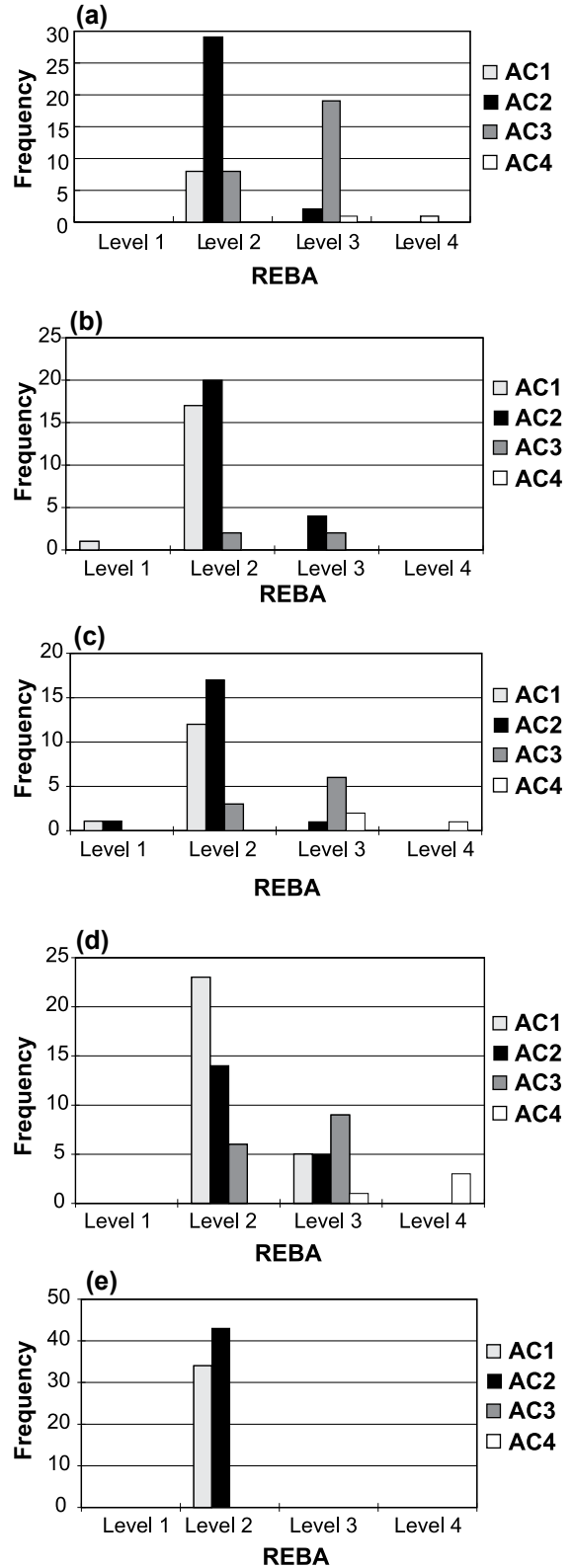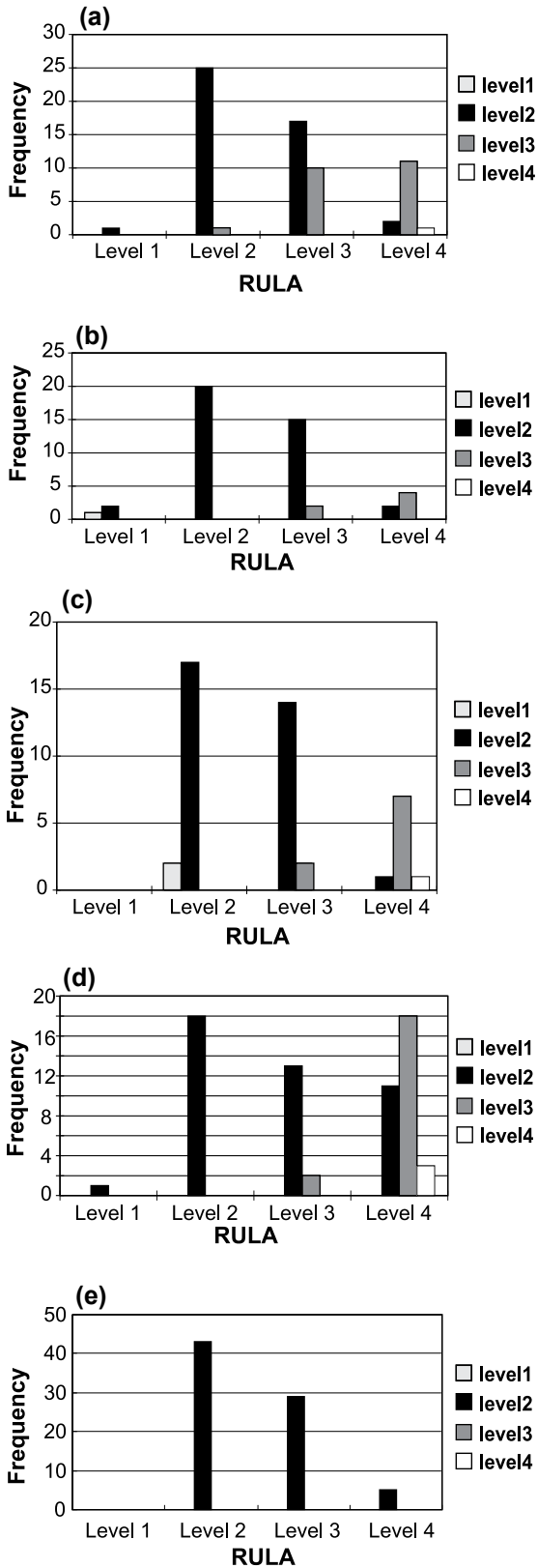

Figure 2. OWAS action categories (AC) and REBA action levels by industry: (a) iron and steel industry, (b) electronics industry, (c) automotive industry, (d) chemical industry, (e) general hospital. *Notes.* OWAS—Ovako Working Posture Analysing System, REBA—Rapid Entire Body Assessment.

Figure 3. RULA and REBA action levels by industry: (a) iron and steel industry, (b) electronics industry, (c) automotive industry, (d) chemical industry, (e) general hospital. *Notes.* RULA—Rapid Upper Limb Assessment, REBA—Rapid Entire Body Assessment.

loads of action level 3 or 4 (12.4%). While there was no extreme case that a posture with action level 4 by RULA was evaluated with action level 1 by REBA, 16 postures with high postural load of action level 4 by RULA were assessed with action level 2 by REBA. Contrary to this general trend for underestimation of scores, REBA overestimated five postures assessed with action level 1 or 2 by RULA (two postures of 49 maintenance tasks in the iron and steel industry, two for a lifting task and an inspection task in the electronics industry, and one for a general task in the chemical industry, Figure 3). The coincidence rate for assessed postural loads between RULA and REBA was distributed from 34.8% in the chemical industry, to 55.8% in the service industry of general hospital.

3.2. Comparison by Work Task Type

The 301 postures were classified into three groups according to the type of tasks performed by workers. These groups were as follows: (a) lifting tasks, including lifting and force exertion activities (89 postures); (b) general tasks, such as assembly, maintenance, inspection, test, etc. (199 postures); and (c) seated task, such as driving vehicles, VDT (video display terminal) tasks, monitoring display panel, etc. (13 postures). Distribution of action category/level by the technique used and task type is presented in Table 2. OWAS exhibited a tendency to underestimate postural loads irrespective of task type, compared to RULA ($p < .002$), while REBA showed the tendency in only lifting and general tasks ($p < .0001$). Specifically, while OWAS and REBA assessed about 68 and 62% of 89 lifting-related postures with action category/level 1 or 2, respectively, RULA evaluated about 76% of the postures with action level 3 or 4. In the general and seated task categories, OWAS and REBA estimated about 84–100% of corresponding postures with action category/level 1 or 2. Postural loads by REBA were significantly higher than those by OWAS irrespective of task type ($p < 0.004$).

3.3. Comparison by Postural Balance

Another comparison was made with respect to leg postural balance. The "balanced" posture was defined as the posture where the body weight was evenly distributed on two legs and feet (body balance). If legs and feet were not in an evenly balanced posture, the posture was classified as "unbalanced". The 301 postures were composed of 247 balanced and 54 unbalanced postures. The results showed that without regard to leg postures, OWAS and REBA underestimated posture-related stress, compared to RULA ($p <$ 0.0001). While OWAS and REBA rated about 85 and 77% of balanced postures with action category/level 1 or 2, respectively, RULA did about 51% of the postures with action level 3 or 4 (Table 3). OWAS and REBA assessed about 52 and 55% of unbalanced postures with action category/level 3 or 4, respectively, whereas RULA did about 80% of the postures with the same level. The proportion of underestimated postures by OWAS and REBA was much lower in unbalanced than in balanced body postures. This implies that because it categorizes varying body postures into just two classes of balanced and unbalanced, RULA may have some limitations in estimating postural load for unbalanced body postures. However, RULA generally overestimated postural loads without regard to classification of lower body (legs and feet) postures, compared to OWAS and REBA. In addition, REBA overestimated postural loads for balanced postures, compared to OWAS ($p < .0001$), while postural loads for unbalanced postures by REBA were not significantly different from those by OWAS ($p > .53$).

TABLE 2. Distribution of Action Category/Level for 301 Postures by Method and Task Type (%)

Task Type	Method	Action Category/Level			
		1	2	3	4
Lifting task	OWAS	34.8	33.7	25.9	5.6
	RULA	0.0	23.6	31.5	44.9
	REBA	0.0	61.8	33.7	4.5
General work	OWAS	33.2	50.8	15.0	10.0
	RULA	2.5	47.2	38.2	12.1
	REBA	1.5	84.9	13.1	0.5
Seated work	OWAS	69.2	30.8	0.0	0.0
	RULA	0.0	84.6	7.7	7.7
	REBA	0.0	92.3	7.7	0.0

Notes. OWAS—Ovako Working Posture Analysing System, RULA—Rapid Upper Limb Assessment, REBA—Rapid Entire Body Assessment,
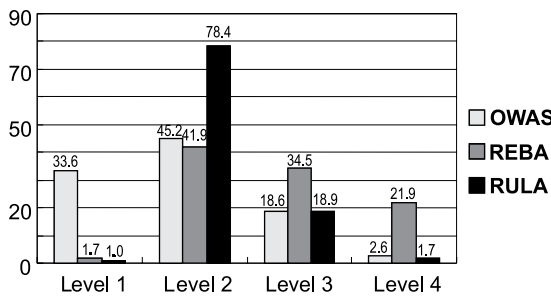
TABLE 3. Distribution of Action Category/Level for 301 Postures by Method and Body Balance (Legs) Posture (%)

Body Balance (Legs) Posture	Method	Action Category/Level			
		1	2	3	4
Balanced	OWAS	38.9	46.6	13.3	1.2
	RULA	2.0	46.6	33.6	17.8
	REBA	2.4	74.9	21.1	1.6
Unbalanced	OWAS	9.3	38.9	42.6	9.2
	RULA	0.0	20.4	40.7	38.9
	REBA	0.0	44.4	53.7	1.9

Notes. OWAS—Ovako Working Posture Analysing System, RULA—Rapid Upper Limb Assessment, REBA—Rapid Entire Body Assessment,

3.4. Comparison by Technique

Without considering industry, work type, and body balance, the proportion of action category/level by techniques applied was calculated in order to look at the overall tendency of assessment (Table 4, Figure 4). The proportion of action category/level 1 or 2 accounted for about 78 and 79% in OWAS and REBA, respectively, but the proportion was no more than 44% in RULA, which was nearly half of that of OWAS and REBA. On the other hand, RULA evaluated about 56% of 301 postures with action level 3 or 4. It can be stated that this confirms relative underestimation tendency of OWAS and REBA for postural load assessment. This was backed up by the Wilcoxon sign test ($p < .0001$). The test also revealed that postural stress by REBA was generally higher than that by OWAS ($p < .0001$).

3.5. Inter-Technique Reliabilities

Inter-technique reliabilities for the evaluation results of action category/level by industry were also obtained (Table 5). Although they differed depending upon the industry type, most of the reliabilities were lower than 60%. Overall, the reliabilities between OWAS and RULA, RULA and REBA, and OWAS and REBA were 29.2, 48.2, and 54.8%, respectively. In general, the coincidence rates for low postural load of action category/level 1 or 2 were far higher than those for whole postural loads. The inter-technique reliability for action category/level 1 or 2 between RULA and REBA amounted to 94.7%, ranging from 89.5 to 100%, which was much higher than that between OWAS and RULA, and OWAS and REBA. This implies that higher postural load levels resulted in more diverse assessment scores reflecting greater disagreements of results between the three observational techniques.

Figure 4. Distribution of action category/level for 301 postures by technique (%). *Notes.* OWAS—Ovako Working Posture Analysing System, REBA—Rapid Entire Body Assessment, RULA—Rapid Upper Limb Assessment, level—action category or action level.

TABLE 4. Distribution of Action Category/Level for 301 Postures by Method

Method	Action Category/Level (%)			
	1	2	3	4
OWAS	33.6	45.2	18.6	2.6
RULA	1.7	41.9	34.5	21.9
REBA	1.0	78.4	18.9	1.7

Notes. OWAS—Ovako Working Posture Analysing System, RULA—Rapid Upper Limb Assessment, REBA—Rapid Entire Body Assessment.

TABLE 5. Coincidence Rate of Evaluation Results Between Techniques (%)

Industry	OWAS/RULA	RULA/REBA	OWAS/REBA
Iron and steel	47.1 (66.7)	52.9 (92.6)	70.6 (74.4)
Electronics	30.4 (52.2)	50.0 (91.3)	50.0 (50.0)
Automotive	34.1 (47.3)	45.5 (89.5)	56.8 (56.3)
Chemical	21.2 (31.6)	34.8 (94.7)	39.4 (29.7)
General hospital	16.8 (30.2)	55.8 (100)	55.8 (55.8)
Overall	29.2 (44.3)	48.2 (94.7)	54.8 (52.7)

Notes. The numbers in parentheses indicate inter-technique reliability of action category/level 1 or 2; OWAS—Ovako Working Posture Analysing System, RULA—Rapid Upper Limb Assessment, REBA—Rapid Entire Body Assessment.

4. DISCUSSION AND CONCLUSIONS

In this study, the observational techniques of OWAS, RULA, and REBA were compared based on the results for 301 different postures. The results showed that regardless of industry, task type, and body balance, OWAS and REBA underestimated posture-related risk compared to RULA. Overall, while OWAS and REBA assessed most of the 301 postures with low postural loads of action category/level 1 or 2 (78.2 and 79.4%, respectively), RULA assigned more than half of the postures (56.4%) with high loads of action level 3 or 4. The inter-technique reliability for postural loads between OWAS and RULA was much lower than that between RULA and REBA, and OWAS and REBA. Those results imply that OWAS assesses postural loads quite differently as compared to RULA.

The three observational techniques compared in this study had been developed based on sets of different postures from a variety of industries and published literature. Each technique has its own strengths and weaknesses depending upon the industries or assumptions made. Since it was originally developed in the steel industry, OWAS was known to be suitable for manual materials handling tasks with high biomechanical low-back loading frequently performed in the iron and steel industry. However, OWAS estimated postural loads for 68 postures taken in an iron and steel company to be lower than assessments by RULA. This means that compared to RULA, OWAS failed to correctly identify high biomechanical low-back loading. Although it was originally designed to be sensitive to the type of unpredictable working postures found in the health care industry, REBA assessed all 77 postures in the general hospital with the same action level 2, and underestimated postural loads for these postures, compared with RULA. Furthermore, RULA with just two classes of body balance (leg postures) produced more discriminatory power regardless of balanced and unbalanced leg postures, as compared to OWAS and REBA with more classes for leg postures.

RULA had also some problems in classifying working postures: (a) the neutral posture of the wrist, neck, and trunk with posture code of 1 is defined as the posture where any corresponding joint motion does not occur (i.e., the angle of corresponding joint motion is 0°), but such a posture is rarely found in real working situations; (b) varying leg postures are categorized into only two classes of balanced and unbalanced. This was improved in REBA, by defining the neutral postures as postures with some ranges of the angular deviations of the corresponding joints, and by categorizing leg postures into four classes.

A high proportion of jobs with high postural load is not an indication that a method is superior to others. It would remain unknown which method better reflects underlying risks for varying tasks, unless some measures of morbidity are brought into analysis. Furthermore, the three techniques were developed for different purposes, and were meant to capture different type of risks. However, RULA might be thought to show more precision in assessing posture-related loads, based on the aforementioned findings and the following: (a) as stated earlier, OWAS and REBA showed a tendency to underestimate postural loads even in the iron and steel, and health care industries, respectively, which were generally known to be suitable for their application; (b) Miedema et al. [38] pointed out that on the basis of maximum holding times for 19 postures, the holding time classification with three categories of postures (*comfortable*, *moderate*, and *uncomfortable*) corresponded well with classifications based on biomechanical and anthropometric data, but that their classifications for 10 of the 19 postures studied were different from the OWAS classification. OWAS was looser than the holding time classification; (c) in the present study, OWAS and REBA resulted in significantly underestimated postural loads for some postures assessed with high postural stress by RULA. Of postures with the highest postural load of action level 4 by RULA, 10 postures were assessed with action category 1, 20 postures with action category 2 by OWAS, and 21 postures with action level 2 by REBA; (d) furthermore, Moon [39] compared the maximum holding times with postural loads by the three techniques for 18 symmetric and asymmetric whole body postures.

Overall, OWAS and REBA were less sensitive to postural stress than RULA, and OWAS and REBA underestimated postural load for the considered postures, compared to RULA. This underestimation was also found in KOSHA's research [40]. That research showed that OWAS, RULA, and REBA assessed 8.9, 24.6, and 3.3% of 51 120 working postures from ship building, automotive, electronics, general manufacturing, and service industries, respectively, with action category/level 3 or 4. REBA evaluated none of the postures with action level 4. The proportion of the postures estimated with high load of action category/level 3 or 4 was much lower in the KOSHA study than in this study. This was because while KOSHA randomly sampled the 51 120 working postures from varying industries, this study took and assessed the postures that the field observers classified as stressful to the human musculoskeletal system; and (e) in view WMSD prevention, it may be more advantageous for a company to assess the relevant postural risk factors more rigorously and firmly, and to over- rather than underestimate the potential risks for WMSDs in order to provide greater motivation for work redesign and improvement of facilities and the working environment following the assessment results.

The fact that RULA identified more jobs as hazardous is not simply the result of more jobs with hand-intensive tasks being analyzed, because (a) most tasks analyzed in this study, except for seated tasks, can not categorized as hand-intensive; and (b) the number of hand-intensive seated tasks was too small (13 tasks). It should be noted that since none of the three techniques have been validated, the relationship between the results of the analysis may not directly infer WMSDs risk.

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