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The Inter-Rater And Intra-Rater Reliability Analysis Of Workplace Ergonomic Risk Assessment

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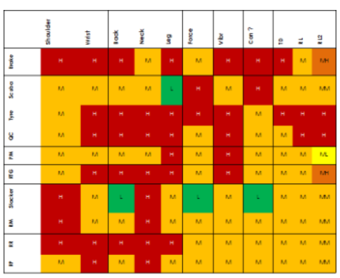
Graphical abstract



Abstract

Observation tools have found wide application in ergonomic assessment of musculoskeletal disorders (MSD) because of their ease of use, ability to be used by multiple users with less specialised training and less operation time. However, their major challenge remains the reliability of their findings. Since MSD is a multidisciplinary problem, there is need for observation tools to be precise when used by practitioners from different professions. This study therefore, investigated the intra-rater and inter-rater reliability of workplace ergonomic risk assessment (WERA) observation tool. Thirteen ergonomics and safety stakeholders, from four different professions were trained and thereafter, independently asked to carry out risk assessment of ten different videos-captured work activities. WERA was used to evaluate the participants' exposure to six physical risk factors of MSDs in six body regions, so as to determine their risk level. The assessment was repeated after two weeks. The interclass reliability analysis was carried out using the intraclass correlation coefficient (ICC) with the two-way mixed model and absolute agreement as the preferred types. Two of the tasks, tyre extraction and quay crane operation were rated as high risked with an exposure rating greater than 60%, while the remaining eight were medium-risked. The body regions with high probability of MSD exposure were the neck (70%), leg (60%), wrist (60%) and back (50%). Inter-rater reliability (ICC) of the activities by the professionals ranged between 0.97 and 0.99 while intra-rater reliability of the participants ranged between 0.81 and 1.0. The reliability analysis demonstrated consistency among the different professionals using WERA. Therefore,there is a need to urgently redesign the tasks and carry out ergonomic interventions in the work activities assessed.

Keywords: Ergonomics, observation tools, risk assessment, work-related musculoskeletal disorders

Abstrak

Aplikasi alat pemerhatian dalam penilaian ergonomik gangguan muskuloskeletal (MSD) adalah sangat luas kerana ianya sangat mudah untuk digunakan oleh para penyelidik, keupayaan untuk digunakan oleh pelbagai pengguna tanpa latihan khusus dan kurang masa operasi. Walau bagaimanapun, cabaran utama para penyelidik ialah kebolehpercayaan penemuan mereka. Isu MSD merentasi disiplin, terdapat keperluan untuk alat pemerhatian ini menjadi jitu apabila digunakan oleh pengamal dari profesion yang berbeza. Kajian ini mengkaji kebolehpercayaan alat pemerhatian antara rater penilaian risiko ergonomik (WERA) tempat kerja. Tiga belas pengamal ergonomik dan keselamatan daripada empat profesion yang berbeza telah dilatih dan selepas itu, secara bebas diminta untuk membuat penilaian risiko sepuluh aktiviti kerja melalui tangkapan video. WERA telah digunakan untuk menilai pendedahan peserta untuk enam faktor risiko fizikal MSDS di enam kawasan badan serta untuk menentukan tahap risiko mereka. Penilaian ini telah diulang selepas dua minggu. Analisis kebolehpercayaan interclass telah dijalankan dengan menggunakan pekali korelasi intraclass (ICC) dengan kedua-dua hala model campuran dan perjanjian mutlak. Dua daripada aktiviti kerja, pengekstrakan tayar dan kren jeti telah dinilai sebagai aktiviti kerja berisiko tinggi dengan pendedahan rating lebih daripada 60%, manakala baki lapan aktiviti kerja adalah berisiko sederhana. Kawasan badan yang mempuyai kebarangkalian pendedahan MSD yang tinggi ialah leher (70%), kaki (60%), pergelangan tangan (60%) dan belakang badan (50%). Kebolehpercayaan antara rater (ICC) untuk aktiviti kerja yang dinilai oleh profesional adalah antara 0.97 dan 0.99 manakala kebolehpercayaan antara rater untuk aktiviti kerja yang dinilai oleh peserta adalah di antara 0.81 dan 1.0. Analisa kebolehpercayaan telah menunjukkan konsisten di kalangan profesional yang berbeza dengan menggunakan WERA. Oleh itu terdapat keperluan segera mereka bentuk semula tugas dan menjalankan intervensi ergonomik dalam aktiviti kerja yang dinilai.

Kata kunci: Ergonomik, alat pemerhatian, penilaian risiko, gangguan muskuloskeletal berkaitan kerja

1.0 INTRODUCTION

Work-related musculoskeletal disorders (WMSDs) remain a serious problem among workers [1]. The problem mostly results from failure to attend to common complains of pains or minor injuries in different parts of the body [2]. Organisations and governments have been spending huge funds on health claims and also research that could provide solutions to the problem. In the US, it accounted for more than 25% of the workplace related injuries [3,4]. WMSD cases were also reported to be responsible for 25.2% of all occupational injuries claims from 2009 to 2014 in Malaysia [5].

Being a multifactoral and complex problem, a major challenge is the credible assessment of the problem [6]. Researchers are employing the three major methodologies, which are objective, observation and survey tools to capture as many facets of the problem as possible [7]. This is necessary because of the subjective nature of pain and multiple indices are required for effective measurement [8,9]. Objective measures employ laboratory calibrated equipment to investigate causal factors, observation tools employs validated checklists to identify relationships while survey tools are based on subjective reports by individuals affected by the disorders. Objective or experimental findings are more credible, but are time consuming, cannot be used for many participants within a short period of time and require specialized training to handle the equipment. Observation tools overcome these problems and have found wide applications among WMSDs stakeholders. This is because of their simplicity, less cost and ease of use. The results are also independent of the bias of the users.

However, One major challenge of the use of observation tools has been the validity and reliability of the instruments [7]. Most of the published reliability focused on intra-rater reliability. However, WMSDs is multidisciplinary and there is a need for such observation tools to produce similar findings among users from different disciplines as intra- and inter rater observability constitute a critical component of reliability [2]. When reliability studies were properly conducted, studies have reported that the results from their use can be as reliable as those obtained from more complex objective tools [2]. Studies have also highlighted its similarity with objective measures [8,9]. Significant association was reported between WMSDs score using WERA tool and self-reported WMSDs among construction workers [10]. This gives observation tool a vintage advantage over objective instrument. Although, a previous study investigated the intra-rater reliability of WERA, this study investigated both the intra rater and inter rater reliability of the WERA tools so as to further validate the usefulness of WERA.

2.0 METHODOLOGY

Instrument

The workplace ergonomics risk assessment (WERA) is an ergonomic tool that evaluates participants exposure to six physical risk factors of WMSDs; which are workers' posture, contact stress, task repetition, level of forcefulness, degree of vibration and task duration [10]. These parameters are confirmed to have an established relationship with WMSDs [2]. The tool also lay emphasis on the posture of the workers because posture and force has been identified as the most important factors associated with WMSDs [2]. Hence, workers posture in five body parts, which are shoulder, wrist, back, neck and leg were observed. The tool has three risk level; low (an indication of an acceptable task), medium (indicates that a task requires investigation in order to effect changes), and high (an unacceptable task). The score for the risk factors are interaction between two factors that forms a matrix ranging from 2 to 6. The interaction between the posture adapted in each body region and the level of repetition gives the scores for the five body regions. The scores for forceful, vibration and contact stress is an interaction between the factor and the posture adopted while working. The score for task duration is an interaction between time spent working and the degree of forcefulness. The final score is an accumulation of the scores from the five body regions and the four other physical factors. The general risk level is obtained classifying the final score into three risk levels, low level is 18-27, medium is 28-44 and high risk is greater than 44.

Participants

Thirteen workers from different departments in a material handling organization participated in a one-day training. This is to familiarize them with the use of WERA for assessing the problem of WMSDs and its identification among workers. They comprise four inspections and enforcement officers from the Department of safety and health (DOSH) and another four workers from the organisation's health monitoring departments (HM). These two categories of workers are ergonomics and occupational health and safety professionals. Five non-ergonomics field professionals were also selected so that they could also monitor and identify risky tasks during working hours. They are three supervisors/foremen from different departments (FW), and two security personnel (P). They were subsequently trained on the use of WERA as an observation tool. The training is to improve their ability to accurately rate the workers. Workers were divided into groups to visit different departments and video record different variable and mono-task works. A total of ten activities was recorded, which includes

1. Automobile brake preventive maintenance
2. Lifting of self-contained underwater breathing apparatus (SCUBA) cylinders
3. Automobile tyres preventive maintenance
4. Quay Cranes (QC) operator
5. Prime Mover (PM)
6. Rubber Tyred Gantry (RTG) Crane operator
7. Stacker
8. Reefer
   i. Monitoring
   ii. Repair
   iii. Plug inspection (PIPO)

The video recording of the tasks were carried out based on the recommendation of NIOSH [7]. Multiple cycles of each task were recorded from different positions for better identification of risk factors. The recordings lasted for 15-30 minutes and each task had 2-3 recordings because most of the tasks were asymmetrical and multiple views of the tasks were necessary for effective analysis. The cameras were also positioned perpendicular to the plane of motion so as to avoid perspective error. All the recordings were completed in the same day. Thereafter, the team assembled at the training centre and were allowed to watch each clip twice. Thereafter, they scored the various activities on their exposure to WMSDs using the WERA observation tool. Without informing the participants of a planned visit, the researchers returned to carry out a re-test, two weeks after the completion of the initial test. However, only eight of the initial participants, representing about 62% were available to participate in the retest. The participants were also allowed to analyse only seven of the initial ten activities because of limited time approved for the retest activity by the organisation.

Statistical Analysis

The interclass reliability analysis was carried out using the intraclass correlation coefficient (ICC), utilising the two-way mixed model and absolute agreement as the preferred type. For the intraclass reliability, consistency was selected as the preferred type. The ICC value below 0.5 was interpreted as poor reliability, 0.5-0.75 was interpreted as moderately reliable while ICC value greater than 0.75 was interpreted as good or high reliability [9, 11]. All analysis was conducted at the 95% confidence interval using the statistical package for social science (SPSS) version 18.

3.0 RESULTS AND DISCUSSION

WMSDs Prevalence among Workers

Postural Risk Factors:
Note: The values in the bracket indicate the percentage of the raters that agreed with the ratings.

Shoulder: the raters (participants) identified five tasks as highly exposed to WMSDs at the shoulder. The tasks are Stackers (69.2%), reefer monitoring (84.6%), reefer repair (76.9%) and brake (53.8%) and QC (58.5%). Also, Scuba (84.6%), RTG (92.3%), reefer PIPO (92.3%), tyre (69.2%), PM (61.6%) was rated as medium risk tasks.

Wrists: Six tasks; Brake (92.3%), tyre (61.5%), QC (92.3%), RTG (84.6%), reefer PIPO (84.7) and reefer repair (53.9%) were rated as highly exposed to WMSDs in the wrist and five other tasks, scuba (76.9%), PM (76.9%), stacker (53.8%) and Reefer monitoring (84.6%) were rated to have medium exposure.

Back: Brake (69.3%), tyre (100%) QC (100%), RTG (100%), reefer repair (69.3%) were rated as highly exposed to WMSDs at the back while scuba (76.9%), PM (61.5%), reefer monitoring (61.5%), reefer PIPO (61.5%) were rated as medium risked.

Neck: Workers involved in six tasks; Tyre (69.2%), QC (100%), RTG (100%), stacker (92.3%), Reefer monitoring (53.8%), reefer repair (76.9%) were highly exposed to WMSDs at the neck region and another three tasks; Brake (53.8%), PM (53.9%) and reefer PIPO (76.9%) were medium risked.

Leg: Brake (100%), tyre (100%), QC (69.3%), PM (61.6%), reefer repair (92.3%) were rated high risked while stacker (92.3%), reefer monitoring (61.5%), reefer PIPO (92.3%), RTG (61.6%) were rated medium risked.

Exposure Due to Other Physical Risk Factors

Forcefulness: two of the tasks, scuba (61.6%) and tyre (100%) were rated as highly forceful while Brake (76.9%), QC (100%), PM (61.6%), RTG (92.3%), reefer monitoring (84.6%), reefer repair (92.3%), Reefer PIPO (61.5%) have medium exposure to WMSDs.

Vibration: Brake (61.5%), tyre (92.3%), QC(100%), PM (61.6%), RTG (53.8%) were sufficient enough to cause high risk exposure to WMSDs and Scuba (53.9%), stacker (76.9%), reefer monitoring (53.8%), Reefer repair (84.6%), PIPO (76.9%) was at medium risk.

Contact stress: three of the tasks, Brake (69.4%), scuba (69.2%) and QC (53.9%) were rated to be highly excessive while tyre (53.9%), PM (76.9%), RTG (61.6%), reefer monitoring (53.9%), reefer repair (61.6%), PIPO (84.6%) were medium risked.

Task Duration: the duration at which workers are engaged in the brake (69.3%) and tyre (100%) were rated to be too high. The other tasks, scuba (76.9), QC (69.2%), PM (84.6%), RTG (76.9%), stacker (69.2%), reefer monitoring (100%), reefer repair (76.9%) and PIPO (61.5%) were rated to be medium risked.

Figure 1 shows the general level of risk exposure for each task. However, most of the tasks are identified as medium risk. Hence, the medium scale was reclassified according to medium high (approximately 4), medium (approximately 3) and medium low (greater than 2 but less than 3) in order to prioritise counter measures that need to be taken accordingly. Figure 2 shows the reclassified risk exposure level to WMSDs while Table 1 shows the final contingency table for the reclassified risk on body parts for respective tasks.

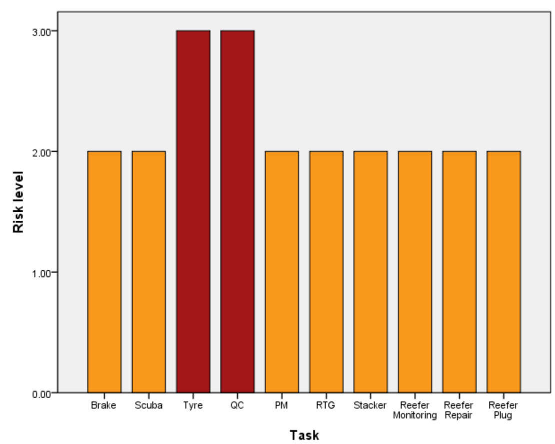


Figure 1 general level of risk exposure for each task

Figure 2 Reclassified level of risk exposure for each task

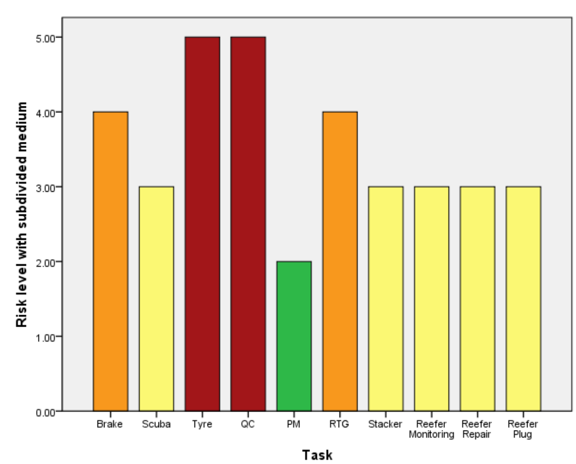


Table 1 The Final Contingency Table for Risk on Body Parts for Various Tasks
(H: High, MH: Medium high, MM: Medium medium, ML: Medium low, L: Low)

	Shoulder	Wrist	Back	Neck	Leg	Force	Vibr	Con 6	TD	RL	RL2
Brake	H	H	H	M	H	M	H	H	H	M	M H
Scuba	M	M	M	M	L	H	M	H	M	M	M M
Tyre	M	H	H	H	H	H	H	M	H	H	H
QC	M	H	H	H	H	M	H	M	M	H	H
PM	M	M	M	M	H	M	H	M	M	M	M L
RTG	M	H	H	H	H	M	H	M	M	M	M H
Stacker	H	M	L	H	M	L	M	L	M	M	M M
RM	H	M	M	H	M	M	M	M	M	M	M M
RR	H	H	H	H	H	M	M	M	M	M	M M
RP	M	H	M	H	M	M	M	M	M	M	M M

RL: Risk level, RL2: Reclassified risk level

(i) Inter-rater Reliability

The inter-rater reliability of the finding is presented in Table 2. This is a measure of the degree of agreement among the raters who observe and evaluate the degree of exposure of the workers to WMSDs and also the reliability of the tool. Reliability Analysis.

Intra rater reliability was also carried out to validate the consistency in the rating ability of the team over a period of time. The intra-rater reliability in Tables 3a and 3b were consistent with the findings during the inter-rater reliability as the ICC value also ranges between 0.9 and 1.0.

Table 2 Inter-rater reliability or agreement

Task	DOSH	HM	FW	Security	Total
Brake	0.993 (0.981-0.998)	0.991 (0.977-0.997)	0.996 (0.990-0.999)	0.999 (0.995-1.0	0.994 (0.987-0.998)
Scuba	0.994 (0.985-0.998)	0.982 (0.955-0.995)	0.974 (0.928-0.993)	0.991 (0.961-0.998)	0.973 (0.943-0.991)
Tyre	0.993 (0.982-0.998)	0.998 (0.996-1.0)	0.999 (0.997-1.0)	0.991 (0.953-0.998)	0.995 (0.990-0.999)
QC	0.993 (0.983-0.998)	0.996 (0.990-0.999)	0.999 (0.997-1.0)	0.997 (0.991-0.999)	0.989 (0.976-0.996)
PM	0.989 (0.974-0.997)	0.979 (0.946-0.994)	0.945 (0.843-0.984)	1.0	0.971 (0.938-0.991)
RTG	0.997 (0.992-0.999)	0.998 (0.996-0.999)	0.996 (0.989-0.999)	0.999 (0.996-1.0)	0.991 (0.980-0.997)
Stacker	0.982 (0.954-995)	0.986 (0.961-0.996)	0.998 (0.993-0.999)	0.992 (0.968-0.998)	0.989 (0.977-0.997)
Reefer Monitor	0.989 (0.972-0.997)	0.985 (0.961-0.995)	0.993 (0.982-0.998)	1.0	0.990 (0.978-0.997)
Reefer Repair	0.985 (0.960-0.995)	0.993 (0.981-0.998)	0.987 (0.964-0.996)	0.962 (0.867-0.990)	0.985 (0.967-0.995)
Reefer plug	0.991 (0.977-0.997)	0.998 (0.994-0.999)	0.996 (0.988-0.999)	0.988 (0.950-0.997)	0.992 (0.983-0.997)

Table 3a Intra-rater reliability or agreement

Task	Brake	Tyre	QC	RTG
Dosh 2	0.995(0.983-0.999)	0.996(0.986-0.999)	0.997(0.990-0.999)	0.998(0.994-1.0)
Dosh 3	0.990(0.962-0.997)	0.998(0.992-0.999)	0.997(0.989-0.999)	0.991(0.967-0.998)
Dosh 4	0.996(0.985-0.999)	0.997(0.990-0.999)	0.992(0.972-0.998)	0.996(0.987-0.999)
HM 2	0.995(0.982-0.999)	0.999(0.995-1.0)	0.996(0.984-0.999)	0.999(0.997-1.0)
HM 3	0.998(0.993-0.999)	0.997(0.990-0.999)	0.988(0.955-0.997)	0.998(0.992-0.999)
HM 4	0.995(0.981-0.999)	0.998(0.992-0.999)	0.997(0.991-0.999)	0.998(0.992-0.999)
FW 1	0.997(0.987-0.999)	0.997(0.990-0.999)	0.996(0.985-0.999)	0.998(0.991-0.999)
P 2	0.998(0.992-0.999)	0.997(0.988-0.999)	0.983(0.940-0.996)	0.998(0.993-0.999)

Table 3b Intra-rater reliability (Continue)

Task	Stacker	Reefer Monitoring	Reefer Repairing	Reefer Plug
Dosh 2	0.999(0.995-1.0)	0.994(0.979-0.998)	0.997(0.989-0.999)	0.981(0.932-0.995)
Dosh 3	0.990(0.964-0.997)	0.999(0.996-1.0)	0.997(0.988-0.999)	0.969(0.890-0.992)
Dosh 4	0.992(0.971-0.998)	0.982(0.934-0.995)	0.983(0.937-0.995)	0.992(0.970-0.998)
HM 2	0.962(0.865-0.990)	0.938(0.786-0.983)	0.987(0.952-0.996)	0.990(0.964-0.997)
HM	0.978(0.920-0.994)	0.991(0.968-0.998)	0.993(0.976-0.998)	0.990(0.962-0.997)
HM 4	0.986(0.948-0.996)	0.997(0.988-0.999)	0.998(0.993-1.0)	0.993(0.975-0.998)
FW	0.988(0.955-0.997)	0.997(0.991-0.999)	0.995(0.983-0.999)	0.979(0.924-0.994)
P 2	0.993(0.976-0.998)	0.945(0.810-0.985)	0.987(0.952-0.996)	0.997(0.988-0.999)

3.1 Discussion

a) Reliability Analysis

The high inter-rater and intra-rater reliabilities show that WERA is a highly reliable observation tool and it can easily be used by different professionals with minimal training [14]. The values of the ICC is a testament that WERA met the criteria of a good observation tool, which include ease of use, repeatability and ability to assess multiple risk factors/body segments [15]. The findings also supported the postulation that video-based observation tools are appropriate in assessing manual material handling tasks [14]. While previous studies have also reported high ICC for observation tools [11,14,15], this is the first tool, to the best of our knowledge that have demonstrated high ICC among ergonomist/occupational safety practitioners and raters from other professions. The similarity between intra-rater and inter-rater reliability is also not common among other observation tools [15].

b) Exposure to WMSDs

The study highlights the significant exposure of workers to WMSDS. To minimise discriminating assessment, this study employs the deferred posture analysis, using video recording, because it affords individual raters to carry out detailed evaluation compared to instantaneous assessment employed in real-time posture analysis [7].

Apart from the purpose of reliability analysis, the use of multiple analysts also improve the validity of observation tools [7]. The risk assessments identified two tasks with high risk thus requiring urgent attention. These are the Quay cranes operators and preventive maintenance staff working on tyres. Two other middle level exposed tasks were also at the verge of becoming high risk. These are RTG operators and the maintenance staff working on the brakes. The tasks are identical as they relate to operators of cranes and staff at the automobile preventive maintenance workshops. These groups of workers have been identified to be working in a high risk environments and there is need to redesign their work environments.

Studies had previously investigated the occurrence of WMSDs among automobile workers [16-19] and crane operators [20-22] because of the high prevalence of WMSDs among them. Unlike what was mostly reported in previous studies that WMSDs are mostly prevalent in the upper extremities, this study shows that WMSDs are also prevalent in the leg region. One of the reasons for the high exposure of automobile workers to WMSDs in this study may be the high degree of manual material handling in their workstation. The non-availability of a maintenance pit also resulted in awkward posture during repair and maintenance operations.

High risks are also identified for the relevant body parts such as the shoulders, wrists, backs, necks, legs for identifying work tasks. The high exposure of the wrist and shoulder is also an indication of excessive manual handling. WMSDs at the back and neck are indication of non-neutral posture during working. The interclass (inter-rater) correlation coefficient (ICC) shows there is absolute agreement on the findings by the various categories of assessors. The ICC values were high enough to be classified as good reliability [9,11]. Hence, the need to analyse and review the findings so that necessary intervention can be carried out.

The risk factors evaluated by WERA have been identified as the most important ones associated with WMSDs [2,4,12]. WERA also investigated the interaction among the risk factors as interaction has not been sufficiently addressed in many of the previous studies [4,12]. The effect of these factors was also incorporated into the findings to provide a comprehensive analysis. Flexibility in assessing WMSDs with WERA was also demonstrated with the ease of converting the initial three levels to five level of risk assessment. Hence, WERA can be adjudge to meet the criteria of risk assessment; which are intra-rater reliability, inter-rater reliability, simplicity, utility and validity [2].

With the established reliability of WERA demonstrated in this study, the use of WERA will go a long way in improving efficiency and job satisfaction among workers [13]. It will help to determine a suitable workload that will not expose the workers to WMSDs. Unlike what was reported about the inability of many previous observation tools to demonstrate high level of intra- and inter- rater reliability [2], this study further demonstrates the suitability of WERA as both the intra- and inter- rater reliability were very high. This also describes the suitability of WERA for multiple tasks analysis.

4.0 CONCLUSION

The study established the excellent intra-and inter-rater reliability of WERA as an observation tool for identifying WMSDs among workers. The minor deviation of the ratings among different professionals indicates the reliability of WERA when used by workers from different backgrounds. Crane operators and automobile maintenance technicians were mostly at risk of WMSDs in the major body region of the wrist, back, neck, shoulder and the leg. This is an indication of the need to apply ergonomic principles in the design of such workstations.

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