A proactive approach to work-related low back pain and other musculoskeletal problems in the workplace

- Application of the QEC System in industry

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Introduction

Low-back pain (LBP) was defined as all conditions of pain, ache, stiffness, or fatigue localised to the lower back (Nachemson and Andersson, 1982). It is reported that nearly 85% of individuals recall back pain symptoms by the time they are 50 years of age (Bigos et al. 1991). Back injuries constitute approximately 24% of all disabling injuries worldwide and represent the greatest cost, both economically and socially (Clark et al. 1988). Back disorders are also the most expensive health care problem in the 30- to 50-year age group, and are the leading cause of disability in working adults under the age of 45 (Kelsey et al., 1978). In the UK, there were about 14 million GP consultations for back pain in 1993 and the annual cost of NHS services for back pain was estimated to be approximately £480 million, along with the lost production costs of about £3.8 billion and DSS benefits of £1.4 billion. It has become obvious that back pain is still an increasing problem especially in industrialised countries despite the efforts of ergonomists, clinicians and legislators (Nachemson, 1996).

Recent European Union and member state initiatives have led to substantial interest in the identification and control of "risk factors" for work-related musculoskeletal disorders (WMSDs). As a result, there has been increased interest in the undertaking of practical risk assessment and ergonomic interventions in the workplace. This calls for the development of a practical exposure assessment tool, particularly for health and safety practitioners, to quickly assess an exposure to WMSD risks for a wide range of tasks. The Quick Exposure Check (QEC) was therefore developed for the assessment of workplace/job risks to the development of low-back pain as well as other types of work-related musculoskeletal disorders in industry.

The development of the QEC system

The development of the QEC system involved the following procedures: (a) Investigation of the potential user needs. (b) Literature research for the "state of the art" related to WMSDs and "risk factors". (c) Critical studies of current techniques for assessing physical exposure in the workplace. (d) Construction, evaluation and improvement of the prototype exposure assessment tool - QEC.

User needs for a practical exposure tool

The potential users' needs were studied via user focus groups and questionnaire surveys among 150-200 health and safety practitioners from the UK. Detailed results of user needs from both focus group and questionnaire studies have been reported elsewhere (Li and Buckle, 1999). In summary, user needs for a new tool included that the method should: be very simple, easy and quick to use; have scores to measure the level of risks; be applicable to a variety of work situations; have an introduction about how to use the method or how to carry out assessment; allow an assessment to be completed in 10-20 minutes; have a sound scientific basis; be comprehensive; involve operators; and be reliable.

Scientific evidence

Epidemiologic evidence regarding the role of physical and psychosocial factors in the development of WMSDs has been widely reported (eg. Hagberg et al., 1995), with one of the latest and perhaps the most comprehensive review by Bernard (1997). There is substantial evidence that the major risk factors that should be eliminated or minimised are those related to manual materials handling, repetitive work, static work, segmental vibration, and poor psychosocial work environments. Based on research findings, it is suggested that exposure should be assessed for those 'risk factors' known to be associated with WMSDs, especially in the regions of the back, neck, shoulder/arm, and hand/wrist. More detailed discussions about these occupational risk factors and why/how they are considered/assessed in the QEC system are reported in Li and Buckle (1999).

Development and evaluation of the QEC

The exposure assessment tool was thus developed based on practitioners' needs and scientific evidence for the "state of the art" with respect to a number of risk factors contributing to WMSDs (Appendix 1). One of the main features of the tool is that it brings together the assessment of both the "observer" and the "worker". In addition, multiple risk factors are considered and their combined effects are implemented with a score table. A short and simple training package is attached to the tool (Appendix 2), which explains the meaning of the terms used in the QEC, and some points that may be helpful to the practitioners when making exposure assessments. It was found that, with a short training/self-learning period and some practice, the practitioners could use the QEC without the need to refer to the training package.

The tool has undergone a series of tests for its usability, sensitivity, inter-/intra-observer reliability and measurement validity. Up to 150 practitioners were involved in the tests and some of the previous results have been reported in early publications (Buckle and Li 1997, Li and Buckle 1997). In this paper, the studies of the reliability test of the tool are to be reported, including the results regarding the measurement validity of the QEC system from both laboratory and field studies.

Major functions of the QEC system

The exposure assessment tool has the following major functions:

- It helps the health and safety practitioners to identify risk factors for work-related back injuries as well as other types of musculoskeletal disorders at work.
- It can be used to evaluate the risk exposure level of each job/task for different body regions.
- It suggests action that needs to be taken in order to reduce risk exposure, which may include the type of ergonomic intervention that can be introduced into the workplace/tasks as well as workers' training programmes.
- It can be used to evaluate the effectiveness of an ergonomics intervention in the workplace, i.e., whether a workplace or job redesign has effectively reduced the risk exposure level for potential WMSDs.
- It has the function of educating users (both practitioners and workers) about the musculoskeletal risks in their workpalce.

Evaluation of the QEC system

Sensitivity

The QEC system (an early version) was tested for its sensitivity with several tasks. The aim of the test was to see whether the tool can effectively assess the exposure of the same job before and after an ergonomics intervention, or whether it can detect the differences in exposure levels between different jobs. Details about the experimental study and the results have been reported in Li and Buckle (1997). In summary, the results suggested that the significant changes ($p<0.05$) in exposure in the back, neck and shoulder could be identified with the tool for some of the tasks tested and the tool was sensitive enough to capture even some small aspect of exposure. The study also indicated that some improvement of the early version of the tool was needed, especially for the wrist/hand assessment. Based on the preliminary evaluations of its sensitivity, usability and reliability as reported elsewhere, the QEC system was modified and developed into its present form (V5) as shown in Appendix 1, which was tested further for its reliability and validity.

Inter-observer reliability

Eighteen task recordings were selected from videos containing recorded tasks for various ergonomic field studies. The video selection was based on the consideration that the tasks should cover as wide a range of jobs as practically possible. The videos were edited so that each task lasted for approximately the same length of time (3'30"-3'40"). Pilot test indicated that such duration was adequate for most observers to complete the assessment. The order of the recorded tasks was arranged such that the task characteristics were different between adjacent tasks.

Twenty-four practitioners participated in the test and they all came from health and safety occupations. Their mean age was 41.2 years (SD=9.16, Range=26-59). The average time they had worked in occupational health and safety was 8.8 years (SD=7.33, Range=2-33), and the average experience with risk assessment was 3.0 years (SD=2.59, Range=0-9).

The practitioners (observers) were divided into five groups, and each group assessed the tasks independently. Before watching the videos, the observers spent 5-10 minutes going through the "Guide to the use of the exposure tool", during which they could discuss issues about the use of

the tool. Then the tape was played and the practitioners made their assessments on each task. If anyone could not complete the assessment within the time given, the tape was re-played to make sure all observers could finish their assessment.

Intra-observer reliability

A test-retest was conducted with eight observers assessing the same set of 18 recorded tasks twice in 3-week interval. Their average age was 41.0 years (SD=12.81, Range=26-59), average experience in health and safety work was 7.63 years (SD=6.30, Range=2-20), and average experience in risk assessment was 2.5 years (SD=3.25, Range=0-7).

Validity

The measurement validity of the QEC system was tested by comparing the practitioners' assessment on simulated tasks with computer-aided 3D motion analysis using the SIMI Motion system (Reality Motion Systems, GmbH, Germany). The tasks were designed so that they could be performed at "known" levels of physical exposure to certain parts of the body (posture and frequency of movement). Two types of manual handling tasks and two types of repetitive manual assembly tasks were performed (controlling weight/heights/work distance and frequency of movement). The tasks were randomly performed by one male subject (age: 34 years, stature: 1.72 m), during which the tasks were assessed by 18 practitioners (5 males and 13 females, mean age=41.3 years (SD=9.31, Range=27-58), average time worked in health and safety=5.2 years (SD=3.88, Range=1-18)). The observers were divided into five groups with 3 or 4 people in each group.

Validity tests were also conducted in field studies by comparing 6 practitioners' assessment on a wide range of practical tasks (60 different tasks in total) with detailed video analysis of these tasks performed by an analyst.

The evaluation results of the QEC system

For the test of inter-observer reliability, both Cohen's kappa and percentage agreement were calculated using the data of 24 observers and of those who had 1-7 and 4-7 year's experience in making risk assessment (Table 1). The individual's test-retest results are given in Table 2.

The need to re-wind the tape due to unfinished assessment was experienced only with the first and second tasks. During this early stage, some observers were hesitant with the assessment but after observing up to two tasks, they became familiar with the method and could complete the assessments within the recording time. It was thus suggested that the results from the first two tasks could be biased and they were therefore excluded from further analysis. Table 3 shows some preliminary results for the validity test of the tool in both laboratory and practical work environment.

Table 1. Inter-observer reliability on assessment items as specified in the QEC

Assessment items	24 observers	18 observers with 1-7 years' experience		11 observers with 4-7 years' experience	
	Kappa	Kappa	Percentage agreement	Kappa	Percentage agreement
Back posture (A1-A3)	0.34	0.33	72.6%	0.41	74.8%
Back movement (B1-B5)	0.21	0.17	71.2%	0.19	66.8%
Shoulder/arm posture (C1-C3)	0.50	0.47	80.2%	0.50	78.4%
Shoulder/arm movement (D1-D3)	0.33	0.38	79.3%	0.35	78.2%
Wrist/hand posture (E1-E2)	-	-	78.8%	-	78.3%
Wrist/hand movement (F1-F3)	0.34	0.42	76.4%	0.42	72.7%
Neck posture (G1-G3)	0.20	0.20	64.7%	0.25	69.1%

Table 2. Intra-observer reliability on assessment items as specified in the QEC

Assessment items	8 observers with 0-7 years' experience		3 observers with 5-7 years' experience	
	χ^2 significance level	Kappa	χ^2 significance level	Kappa
Back posture (A1-A3)	p≤0.00001	0.52	P≤0.00001	0.53
Back movement (B1-B5)	P≤0.00001	0.50	P≤0.0003	0.39
Shoulder/arm posture (C1-C3)	P≤0.00001	0.50	P≤0.0001	0.49
Shoulder/arm movement (D1-D3)	P≤0.00001	0.53	P≤0.0003	0.49
Wrist/hand posture (E1-E2)	P≤0.00001	-	P≤0.005	-
Wrist/hand movement (F1-F3)	P≤0.00001	0.50	P≤0.0002	0.47
Neck posture (G1-G3)	P≤0.00001	0.48	P≤0.05	0.32

Table 3. Agreement between observers' assessment and detailed video analysis

Assessment items	Percentage agreement between observers' assessment and SIMI analysis (laboratory study)	Percentage agreement between observers' assessment and video analysis (field study)
Back posture (A1-A3)	87.0%	54.2%(64.5%)
Back movement (B1-B5)	72.3%	91.5%
Shoulder/arm posture (C1-C3)	85.2%	81.3%
Shoulder/arm movement (D1-D3)	87.5%	76.3%
Wrist/hand posture (E1-E2)	-	84.7%
Wrist/hand movement (F1-F3)	-	83.1%
Neck posture (G1-G3)	-	76.3%
Overall agreement		78.2% (79.7%)

Discussion

Inter-observer reliability

The agreement between 24 observers on most assessment items tested indicated a 'fair agreement' by kappa analysis (Landis and Koch, 1977)(Table 1). The agreement of 'experienced' practitioners showed some improvement, particularly for back posture, shoulder/arm and wrist/hand movement, suggesting a 'moderate agreement'. Agreement on back movement was 'slight to fair', suggesting that further improvements are needed for this assessment item. Inter-observer agreement on neck posture was not high. Similar problems have been encountered by other researchers. For wrist/hand posture, kappa analysis was found to be unsuitable due to low data variation between categories.

With percentage agreement, most assessment items were either close to or above 70%. According to Baty et al. (1986), inter-observer agreement of 75% can be regarded as acceptable.

Present studies suggest that QEC has the potential to meet the basic requirement of its inter-observer reliability for most of its items. It should be noted that assessing recorded tasks can be different from assessing real ones, especially with the tasks in the present studies – the recordings' quality varied among tasks (eg. lighting), and they were recorded from either a fixed camera position or from a far distance. Better agreement is expected if the assessment is conducted using real tasks or better video recordings.

Intra-observer reliability

Table 2 shows that intra-observer reliabilities for almost all assessment items reached 'moderate agreement' level, and the test-retest agreements were all statistically significant. The kappa results also suggested that people with/without previous experience in risk assessment are able to reach an agreement at a similar level. This is encouraging because the tool is aimed at non-skilled users and is intended to be used by a person who assesses a job before and after an ergonomic intervention. The 'experienced' observers did not achieve a higher level of agreement for all items as compared to the whole group. One explanation is that time-based experience may not necessarily represent the ability of using the tool. People with experience may be better at judging some types of exposure, but may not be good at assessing other items. It is anticipated that an improved training process may increase the assessment reliability further.

Assessment validity

There is no 'correct' answer as to what the actual exposure is for a practical task. For tasks with 'known' body postures and movement (either controlled or measured by a sophisticated method), most assessment items were 'correctly' measured at an acceptable accuracy level (Table 3). It was found that, in the field studies, one practitioner regarded back flexion of less than 90º as 'moderately flexed' rather than 'extremely flexed', resulting in a high level of disagreement with the detailed video analysis. Further analysis with the results of five observers showed that the agreement on back posture was 64.5%. Another reason for this 'low level' agreement was possibly that the posture was assessed as the 'worst event' which may happen in a short time, during which the observer may not be looking at the worker and therefore missed the recording.

The 'score system' is, at this time, largely hypothetical, which considers the interaction/combination of risk factors. Epidemiologic evidence is still not sufficient to support such a pattern, but some evidence can be found in the literature. It is difficult to determine whether this system is 'true' or 'correct', and equally difficult to determine whether it is 'untrue' or 'incorrect' (it is perhaps a significant achievement if one can do so in either way). At this stage the system serves as a compromise between the 'known' and 'unknown' concerning the 'weighting' and 'interaction' of 'risk factors', and should only be taken as a reference.

Conclusion

QEC is a new method which has been developed for practitioners to assess exposure to the risks of work-related musculoskeletal disorders in the back, should/arm, hand/wrist and the neck. Based on the test results obtained so far, this tool has been found to be sensitive for assessing the change in exposure before and after an ergonomic intervention. The tool is also shown to be largely reliable and applicable to a wide range of jobs. With brief training (self-learning) and some practice, assessment can normally be completed within 10 minutes for each task. However, further improvements are still desirable, particularly for the assessment of frequent body movements. It is anticipated that measurement reliability will improve with regular use of the

tool and further experience of making risk assessments. The practical value of the tool with its proactive or preventative approaches to solving work-related back pain and other health problems may take time to be fully appreciated, which also relies on the co-operation of industrial partners.

(Note: More information about the QEC system is available at: http://www.geocities.com/qecuk/)

Acknowledgements

The QEC system was developed at Robens Centre for Health Ergonomics, European Institute for Health and Medical Sciences, University of Surrey, in collaboration with Professor Peter Buckle, and the research was funded by the HSE. Grateful thanks are due to the researchers at Robens for their support over the course of this work, and to the practitioners for their co-operation.

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Appendix 1: ***Quick Exposure Check for work-related musculoskeletal risks - QEC***

Job title: **Task:** **Assessment conducted by:** **Worker's name:** **Date:** **Time:**

Back

- *When performing the task, is the back*

A1: almost neutral?
A2: moderately flexed or twisted or side bent?
A3: excessively flexed or twisted or side bent?

- **For manual handling tasks only**: *Is the movement of the back*

B1: Infrequent? (Around 3 times per minute or less)
B2: Frequent? (Around 8 times per minute)
B3: Very frequent? (Around 12 times per minute or more)

- **Other tasks**: Is the task performed in static postures most of the time? *(either seated or standing)*

B4: No. B5: Yes.

Shoulder/arm

- *Is the task performed*

C1: at or below waist height?
C2: at about chest height?
C3: at or above shoulder height?

- *Is the arm movement repeated*

D1: infrequently? (Some intermittent arm movement)
D2: frequently? (Regular arm movement with some pauses)
D3: very frequently? (Almost continuous arm movement)

Wrist/Hand

- *Is the task performed*

E1: with almost a straight wrist?
E2: with a deviated or bent wrist position?

- *Is the task performed with similar repeated motion patterns*

F1: 10 times per minute or less?
F2: 11 to 20 times per minute?
F3: More than 20 times per minute?

Neck

- *When performing the task, is the head/neck bent or twisted excessively?*

G1: No
G2: Yes, occasionally
G3: Yes, continuously

Worker's assessment

Name: Job title: Date:

- ***What is the maximum weight handled in this task?***

a1: Light (5 kg or less)
a2: Moderate (6 to 10 kg)
a3: Heavy (11 to 20 kg)
a4: Very heavy

- ***How much time on average do you spend per day doing this task?***

b1: Less than 2
b2: 2 to 4
b3: More than 4

- ***When performing this task (single or double handed), what is the maximum force level exerted by one hand?***

c1: Low (eg. Less than 1 kg)
c2: Medium (eg. 1 to 4 kg)
c3: High (eg. More than 4 kg)

- ***Do you experience any vibration during work?***

d1: Low (or no)
d2: Medium
d3: Hig

- ***Is the visual demand of this task -***

e1: Low? (There is almost no need to view fine details)
e2: High? (There is a need to view some fine details)

- ***Do you have difficulty keeping up with this work?***

f1: Never
f2: Sometimes
f3: Often

- ***How stressful do you find this work?***

g1: Not at all
g2: Low
g3: Medium
g4: Hig

Table of Exposure Scores

Exposure to the **Back**

	A1	A2	A3	Score 1	B1	B2	B3	Score 2	b1	b2	b3	Score 3
a1	*2*	*4*	*6*		*2*	*4*	*6*		*2*	*4*	*6*	
a2	*4*	*6*	*8*		*4*	*6*	*8*		*4*	*6*	*8*	
a3	*6*	*8*	*10*		*6*	*8*	*10*		*6*	*8*	*10*	
a4	*8*	*10*	*12*		*8*	*10*	*12*		*8*	*10*	*12*	
				Score 4				**B4**	**B5**	**Score 5**		**Total score for the back** = Sum of scores 1 to 5
b1	*2*	*4*	*6*		*2*	*4*	*6*	*2*	*4*			
b2	*4*	*6*	*8*		*4*	*6*	*8*	*4*	*6*			
b3	*6*	*8*	*10*		*6*	*8*	*10*	*6*	*8*			

Exposure to the **Shoulder/arm**

	C1	C2	C3	Score 1	D1	D2	D3	Score 2	b1	b2	b3	Score 3
a1	*2*	*4*	*6*		*2*	*4*	*6*		*2*	*4*	*6*	
a2	*4*	*6*	*8*		*4*	*6*	*8*		*4*	*6*	*8*	
a3	*6*	*8*	*10*		*6*	*8*	*10*		*6*	*8*	*10*	
a4	*8*	*10*	*12*		*8*	*10*	*12*		*8*	*10*	*12*	
				Score 4				**Score 5**	**Total score for shoulder/arm** = Sum of scores 1 to 5			
b1	*2*	*4*	*6*		*2*	*4*	*6*					
b2	*4*	*6*	*8*		*4*	*6*	*8*					
b3	*6*	*8*	*10*		*6*	*8*	*10*					

Exposure to the **Wrist/hand**

	F1	F2	F3	Score 1	E1	E2	Score 2	b1	b2	b3	Score 3
c1	*2*	*4*	*6*		*2*	*4*		*2*	*4*	*6*	
c2	*4*	*6*	*8*		*4*	*6*		*4*	*6*	*8*	
c3	*6*	*8*	*10*		*6*	*8*		*6*	*8*	*10*	
				Score 4			**Score 5**	**Total score for the wrist/hand** = Sum of scores 1 to 5			
b1	*2*	*4*	*6*		*2*	*4*					
b2	*4*	*6*	*8*		*4*	*6*					
b3	*6*	*8*	*10*		*6*	*8*					

Exposure to the **Neck**

	G1	G2	G3	Score 1	e1	e2	Score 2	**Total score for the neck** = Scores 1+ 2
b1	*2*	*4*	*6*		*2*	*4*		
b2	*4*	*6*	*8*		*4*	*6*		
b3	*6*	*8*	*10*		*6*	*8*		

Exposure scores: Back: _____Shoulder/arm: _____Wrist/hand: _____Neck: _____

Appendix 2: A guide to the use of the QEC system

This exposure tool has been designed to assess the change in exposure to musculoskeletal risks before and after an ergonomic intervention. Before making the risk assessment, a preliminary observation of the job should be made for at least one work cycle. Record all information as listed at the top of the exposure tool form.

Exposure assessment for the **back**

Back posture (A1-A3)

The assessment for the back posture should be made at the moment when the back is most heavily loaded. For example, when lifting a box, the back may be considered under highest loading at the point when the person leans or reaches forward to pick up the load.

- The back can be regarded as "***Almost neutral***" (Level A1) if the person is seen to work with his/her back flexion/extension, twisting, or side bending less than 20°, as shown in Figure-A1.

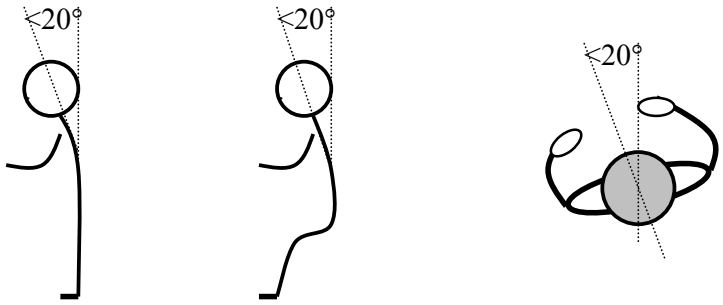

Figure-A1. The back is "almost neutral"

- The back can be regarded as "**Moderately *flexed or twisted***" (Level A2) if the person is seen to work with his/her back flexion/extension, twisting or side bending more than 20° but less than 60°, as shown in Figure-A2.

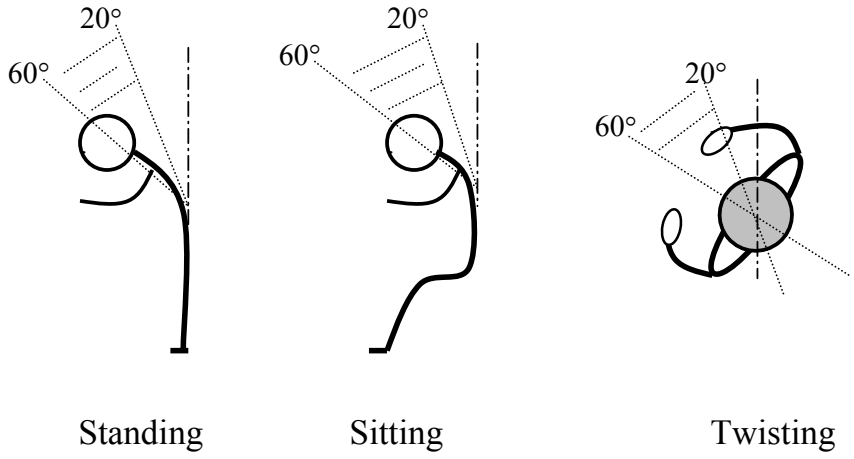

Figure-A2. The back is "flexed or twisted"

- The back can be regarded as "***Excessively flexed or twisted***" (Level A3) if the person is seen to work with his/her back flexion or twisting more than 60° (or close to 90°), as shown in Figure-A3.

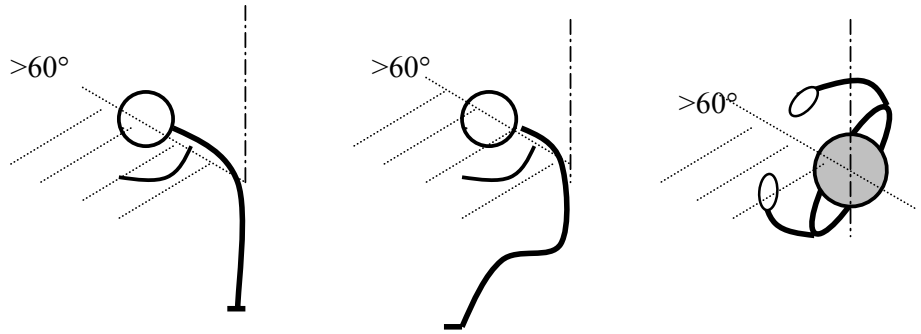

Figure-A3. The back is "excessively flexed or twisted"

Back movement (B1-B5)

- For manual material handling tasks, assess B1-B3. This refers to how often the person needs to bend, rotate his/her back when performing the task. Several back movements may happen within one task cycle.

- For tasks other then manual handling, such as sedentary work or repetitive tasks performed in standing or seated position, ignore B1-B3 and assess B4-B5.

Exposure assessment for the **shoulder/arm**

Shoulder/arm posture (C1-C3)

Assessment should be made when the shoulder/arm is most heavily loaded during work, but not necessarily at the same time as the back is assessed. For example, the load on the shoulder may not be at the highest level when the person bends down to pick up a box from the floor, but may become greater subsequently when the box is placed at a higher level.

Shoulder/arm movement (D1-D3)

The movement of the shoulder/arm is regarded as -

- "***Infrequent***" if there is no regular motion pattern.
- "***Frequent***" if there is a regular motion pattern with some short pauses.
- "***Very frequent***" if there is a regular continuous motion pattern during work.

Exposure assessment for the **wrist/hand**

Wrist/hand posture (E1-E2)

This is assessed during the performance of the task at the point when the most awkward wrist posture is adopted, include wrist flexion/extension, side bending (ulnar/radial deviation) and rotation of the wrist around the axis of the forearm. The wrist is regarded as "***almost straight***" (Level E1) if its movement is limited within a small angular range (e.g. <15°) of the neutral wrist posture (Figure-E1). Otherwise, if an obvious wrist angle can be observed during the performance of the task, the wrist is considered to be "***deviated or bent***" (Figure-E2).

Figure-E1. The wrist is almost straight

Figure-E2. The wrist is deviated or bent

Wrist/hand movement (F1-F3)

This refers to the movement of the wrist/hand and forearm, excluding the movement of the fingers. One motion is counted every time when the same or similar motion pattern is repeated over a set period of time (e.g., 1 minute).

Exposure assessment for the **neck**

The neck can be considered to be "***excessively bent or twisted*** " if it is bent or twisted at an obvious angle (or more than 20°) relative to the torso.

Worker's assessment of the same task

After the observer's assessment is made, ask the worker to answer the questions as shown on the second page of the tool. Explain the meaning of the terms to him/her when necessary.

Calculation of the total exposure scores

The total exposure scores can be obtained by combining the assessments from the 'observer' (A-G) and the 'worker' (a-e). Ensure that the correct combined scores have been determined before adding them into the total.

Additional points:

- *For group work, ensure a sufficiently representative number of individual workers are assessed.*
- *Workers whose daily pattern of work and job demands are variable, should be observed more than once.*