ERGONOMIC JOB MEASUREMENT SYSTEM

By DAVID RIDYARD, LINDA TAPP and LAWRENCE WYLIE

According to the Bureau of Labor Statistics (BLS), in 1997, work-related strains and sprains, most often including the back, accounted for approximately 799,000 cases involving days away from work in private industry throughout the U.S. (BLS 1999). An additional 29,000 carpal tunnel syndrome and 18,000 tendinitis lost-workday cases occurred as a result of repetitive motion, such as typing or key entry; repetitive use of tools; and repetitive placing, grasping or moving of objects other than tools.

While precise costs of occupational musculoskeletal disorders (MSDs) are not known, the National Institute for Occupational Safety and Health (NIOSH) estimates that upper extremity MSDs, which affect the muscles, nerves, tendons and other soft tissues of the neck, shoulder, elbow, hand, wrist and fingers, account for more than $2.1 billion in workers' compensation (WC) costs annually (NIOSH). Additionally, low-back disorders impose a cost of about $11 billion annually on the WC system. AFL-CIO estimates the total cost of MSDs at $209 billion annually (AFL-CIO). Bernard reported that regardless of estimates used, the problem is significant—both in worker health and economic terms.

MAKING ERGONOMIC TEAMS EFFECTIVE

Many companies have established multi-disciplinary ergonomics teams to address rising injury rates, growing numbers of lost-time days and rising WC costs associated with MSDs. These companies recruit team members from various disciplines within the plant, which means ergonomics is often outside the normal scope of their work and job responsibilities. As a result, they may lack the skills, knowledge and experience required to effectively address ergonomic issues.

Often, the most significant challenge the facility team faces is how to assess ergonomic risk factors. It can be a challenge to determine whether manual materials handling activities present high, moderate or low risk of MSDs. It can be even more difficult to express this information to management in a manner that will impact ergonomic risk reduction decision making.

AN ERGONOMIC JOB MEASUREMENT SYSTEM

An ergonomic job measurement system (EJMS) was developed to provide a comprehensive, systematic, easy-to-use method for facility-based teams to assess workplace ergonomic risk factors. The objective of this system is to identify, evaluate and rank cost-effective ergonomic improvements, then drive their implementation to reduce the incidence of significant MSDs.

Various qualitative ergonomic risk assessment tools were evaluated to develop the EJMS (Armstrong and Lachey; Grant and Brophy; Rodgers; Putz-Anderson; Snook and Ciriello; Waters, et al). The goal was to create a simplified assessment tool that required no calculations or extensive computer modeling. A core team of three credentialed professionals (CIHs, CSPs and CPEs) was formed to create and field-test alpha and beta prototypes over a three-year period. Additional peer review and input from facility engineers and management were used to further refine the tool. The EJMS was specifically designed for use by ergonomic teams with only a basic understanding of ergonomic principles and limited practical field experience.

EJMS: FORM & INSTRUCTIONS

The EJMS form facilitates a process that enables management to evaluate, rank order and implement viable ergonomic solutions for workplace hazards with a moderate or high level of risk. The EJMS enables site personnel to conduct consistent ergonomic evaluations.

Precise, accurate scoring of tasks has been reproducibly demonstrated during three years of field testing in a wide variety of industries (e.g., pharmaceuticals, warehousing, petrochemical, beverage and bottling, medical device manufacturing, metal fabrication, electronics) to dramatically reduce both the frequency and severity of ergonomics-related workplace injuries and illnesses. While no evaluation system is all-encompassing, the EJMS can serve as the cornerstone of a results-oriented facility ergonomics program.

The form begins with an informational header that identifies the job or task, the number of workers who perform the task and task-specific data (e.g., number of hours per shift the task is performed; number of days in a month the task occurs; job rotation system in effect). Department and site identification is included for those with corporate or multi-site responsibilities.

An EJMS instruction sheet was developed to provide numerical rankings to help evaluators calculate consistent EJMS scores. Instructions also include an engineering evaluation and management prioritization system; this element drives the actual implementation of cost-effective ergonomic solutions.

ASSESSMENT OF REPETITIVE MOTION & AWKWARD POSTURES

The EJMS is a two-sided form that represents two separate evaluation sections.

Section I addresses repetitive motions and awkward postures (Figure 1). Examples of these conditions are illustrated to provide a general picture of what will be evaluated. Next to each motion/posture, columns are provided to record the force and frequency score.

A force/frequency scoring matrix was developed based on—and validated through—three years of field tests in a diverse range of industrial, high technology and service industries. A task that requires low force and frequency would score zero points, while a task with high force and high frequency would score 20 points. Figure 3 depicts instructions for using the matrix to score "eye strain."

ASSESSMENT OF MANUAL LIFTING TASKS

Section II addresses lifting tasks (Figure 2). An evaluator reviews eight factors associated with a lifting task—weight of load; distance the load is held away from the body; hand height at the beginning of the lift; frequency of lifting; body twisting angle; hand grip; and distance the load is carried. The first seven elements are correlated to the revised NIOSH Lifting Index Model (Waters, et al 749+). A metabolic component for the distance a load is carried has been added to account for lifting fatigue induced by carrying distance.

A score of 1, 5, 10, 20 or 30 points is directly assigned to each lifting factor without the need for graphs or numerical interpretations. Once a score has been determined for each factor, individual scores are added to provide a lifting evaluation subtotal.

DETERMINING THE FINAL ERGONOMIC RISK LEVEL

To determine the final ergonomic risks and priorities, the evaluator takes the following steps.

1) **Subtotal Score.** The subtotal score from the repetitive motion/awkward postures evaluation, or the lifting evaluation, is recorded at the bottom of Figure 2.

2) **Ergonomic Complaints or Injuries.** Zero to 20 points are added to the subtotal score to provide extra weighting for job tasks that have been associated with significant ergonomic complaints or injuries.

3) **EJMS Evaluation (Total Risk Score).** The two scores are added to arrive at the final ergonomic risk level (total risk score).

- A total risk score of 85+ points is classified a high-risk task.
- A total risk score between 45 and 84 points is classified a moderate-risk task.
- A total risk score between zero and 44 points is classified a low-risk task.

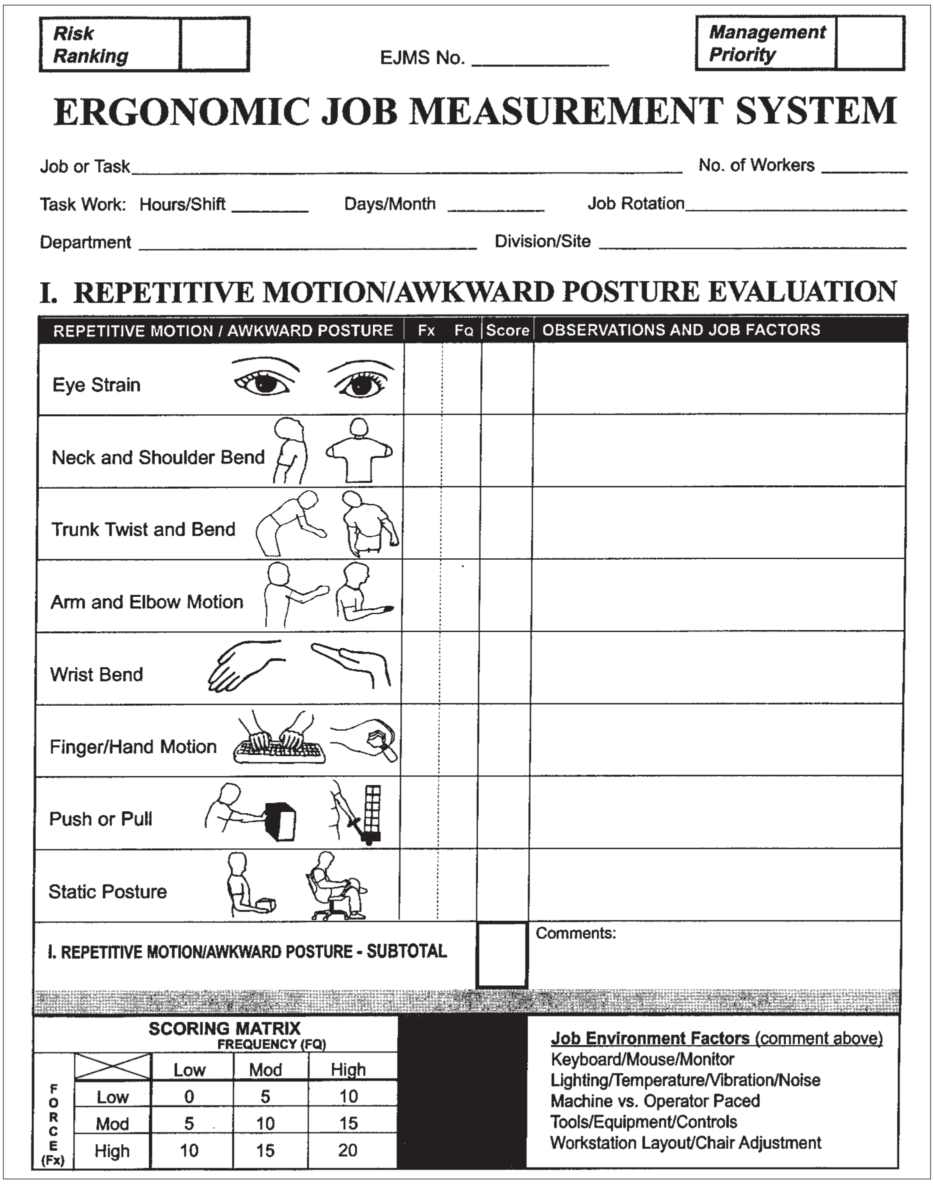
ERGONOMIC SOLUTIONS

The evaluator, usually a member of the facility ergonomics committee, outlines potential ergonomic solutions on the EJMS form. In addition, the evaluator can re-score the EJMS to show the reduction in risk level that will likely be achieved by the proposed corrective actions.

A facility engineer knowledgeable in ergonomic design principles then estimates modification costs and time needed to complete the proposed project. Both short- and long-term solutions may be indicated. Short-term solutions may include "quick fixes," such as raising or lowering work surface height; modifying employee work practices and job methods; and implementing job rotation. Long-term solutions may include automation and/or major equipment changes.

Proper use of the EJMS will help pinpoint specific types of controls that can be used to lower the score by clearly showing where to target corrective actions. A control can be implemented "on paper," and the EJMS re-scored as if the corrective measure was already in place, so that the impact of the control can be determined as seen by a lower score.

FIGURE 1 **EJMS Section I: Repetitive Motion/Awkward Posture**


Risk Ranking | EJMS No. ____________ | Management Priority

ERGONOMIC JOB MEASUREMENT SYSTEM

Job or Task ____________ No. of Workers ________

Task Work: Hours/Shift _______ Days/Month _________ Job Rotation ____________

Department ____________ Division/Site ____________

I. REPETITIVE MOTION/AWKWARD POSTURE EVALUATION

REPETITIVE MOTION / AWKWARD POSTURE	Fx	Fq	Score	OBSERVATIONS AND JOB FACTORS
Eye Strain				
Neck and Shoulder Bend				
Trunk Twist and Bend				
Arm and Elbow Motion				
Wrist Bend				
Finger/Hand Motion				
Push or Pull				
Static Posture				
I. REPETITIVE MOTION/AWKWARD POSTURE - SUBTOTAL				Comments:

SCORING MATRIX

FORCE (Fx) \ FREQUENCY (FQ)	Low	Mod	High
Low	0	5	10
Mod	5	10	15
High	10	15	20

Job Environment Factors (comment above)
Keyboard/Mouse/Monitor
Lighting/Temperature/Vibration/Noise
Machine vs. Operator Paced
Tools/Equipment/Controls
Workstation Layout/Chair Adjustment

FIELD TESTING

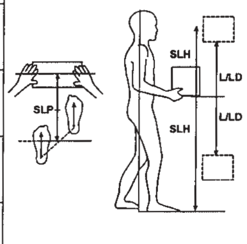
A certified professional ergonomist (a member of the core team) provided customized training to multi-disciplinary ergonomics teams at each facility. This consisted of a one-day initial session (classroom style with facility-specific video) and a one-day follow-up session scheduled after all team members had completed several EJMS forms on their own. This session provided an excellent forum for discussing team member concerns in an attempt to achieve a higher level of consensus. Training was designed to ensure that team members were able to identify, quantify and control of MSD risk factors. Detailed classroom training regarding correct use of the EJMS was completed before the system was field tested. Similar training was provided at each facility to ensure consistency.

The EJMS was field tested at each facility by two "work groups" as well as by the CPE. Thus, three independent analyses were performed for each task. Each facility

FIGURE 2 EJMS Section II: Lifting

II. LIFTING EVALUATION

LIFTING EVALUATION	1 pt.	5 pts.	10 pts.	20 pts.	SCORE	LIFTING OBSERVATIONS
WEIGHT OF LOAD (1) pounds (kilograms)	1-5 (1-2.5)	6-15 (2.6-7)	16-25 (8-13)	26-50 (14-22.5)		Object Weight________
STARTING LOAD POSITION(2)-SLP inches (cm) from body center line	1-9 (0-23)	10-11 (24-28)	12-13 (29-33)	14-16 (34-41)		
STARTING LOAD HEIGHT-SLH inches (cm) above or below waist	<4 (<10)	5-15 (13-40)	16-26 (41-66)	27-40 (67-100)		
LIFT/LOWER DISTANCE-L/LD inches (cm) ↑↓ from start of lift to end	1-14 (1-36)	15-22 (37-56)	23-35 (57-89)	36-70 (90-180)		
FREQUENCY lifts/minute	0.1-0.2	0.3-1	1.1-3	3.1-10 (3)		= Key Evaluation Variables
BODY TWISTING ANGLE degrees	1-15	16-35	36-65	66-135		Comments:
GRIP	Good	Fair	Poor	–		
DISTANCE CARRIED feet (meters)	1-5 (0-1.5)	6-13 (1.6-4)	14-20 (4.1-6)	21+ (6.1+)		
II. LIFTING EVALUATION – SUBTOTAL						(1) If Weight ≥ 51 lbs. Score as 30 pts. (2) If Position ≥ 17 inches Score 30 pts. (3) If task duration > 4 hours Score +10



Ergonomic Ideas ____________________

Ergonomic Evaluator____________________ Date __________

ERGONOMIC RISKS & PRIORITIES EVALUATION				
III.A. ERGONOMIC COMPLAINTS/INJURIES (Percent)	1-5	6-19	20+	SCORE
III.B. ERGONOMIC COMPLAINTS/INJURIES (Pt. Score)	5	10	20	
I./II. REPETITIVE MOTION or LIFTING EVALUATION – – SUBTOTAL ⇒				
IV. EJMS EVALUATION -- TOTAL RISK SCORE				
Ergonomic Coordinator	Risk Ranking: HIGH - MEDIUM - LOW			
Ergonomic Solution __________				
Engineering Review By __________ Date ______				
Estimated Cost / Time __________				

team had between six and 10 members, so three to five employees were assigned to each work group. Most teams included members from management and staff (production managers, line supervisors, engineers, safety professionals, nurses) as well as production employees. One team had only management representatives.

To score the EJMS, a videotape of the task was shown (repeatedly, if necessary) to help team members determine task repetitiveness and analyze postures, exertions and other ergonomic data. Production data, including weights and dimensions of materials, production rates and job rotation schedules were provided. Each work group member scored the EJMS individually, then discussed results with the group, which then reached a consensus work group score. The two work groups and the CPE then discussed results to reach overall consensus.

Figure 4 shows EJMS scores recorded by each work group, the CPE and overall consensus scores for 15 select tasks. Data show a relatively high consistency between the scores of Groups 1 and 2 and those of the CPE. The average variance between the lowest and highest of the three scores for each task is approximately 14 percent. Excluding the four tasks with a variance greater than 20 percent (indicated by footnotes *1 to *4), the average variance for the 11 remaining tasks is approximately nine percent. The overall EJMS score (last column of the table) indicates the overall consensus EJMS score.

DISCUSSION OF FIELD TESTING RESULTS

1) Field-test data show a relatively high consistency between the scores of ergonomics team members and the CPE.

2) Scoring variances for 11 of the 15 tasks correlated to an average difference of six points for each task. This difference is relatively minor and would generally not affect a task's overall risk classification.

3) Scoring variances for four tasks correlated to an average difference of 17 points. A major risk factor was missed by at least one scoring group when scoring these four tasks. Overall consensus was relatively easy to obtain once that factor was identified and discussed.

4) Ergonomics team members found it easiest to score lifting tasks. However, significant mistakes were made if the degree of body twisting associated with the task was not carefully observed and analyzed.

5) Short-duration repetitive tasks (less than 30 minutes) were more difficult to analyze than long-duration tasks. Jobs that entail many short-duration tasks (such as maintenance at a group refinery) required evaluators to time-weight scores of each short-duration task in order to obtain a full-shift EJMS score. This was achieved using the following equation (similar to time-weighting noise or chemical exposures):

$$\text{Full-shift EJMS score} = \frac{(EJMS_1 \times C_1) + = (EJMS_2 \times C_2) + = (EJMS_3 \times C_3) \ldots + (EJMS_N \times C_N)}{8 \text{ hours}}$$

Where: $EJMS_{1 \ldots N}$ = analysis of each short-duration task of employee's shift.
C_1 = hours to complete each short duration task of employee's shift

6) Team members reported the following concerns during field tests:

•*Difficult to analyze short-duration repetitive tasks.* This concern was addressed with the time-weighting system.

•*Difficult to assess prolonged static posture levels.* Additional team training was provided and the instruction form for static posture scoring was revised.

•*Difficult to understand lifting analysis risk factors.* A diagram was added to the EJMS form.

7) Team members reported that the EJMS was relatively easy to use after they scored a few (more than four) tasks. Many

FIGURE 3 Scoring Eye Strain

Eye Strain	Intense focus required under poor illumination and/or glare conditions.	Relaxed visual tasks with good illumination and low-glare conditions.	Constant visual concentration on fixed point (close inspection of fast-moving items; intense computer use).	Occasional to intermittent visual concentration (e.g., occasional computer keying activities).

FIGURE 4 EJMS Scores

Work Task Description	Type of Industry	EJMS Score (Group 1)	EJMS Score (Group 2)	EJMS Score (CPE)	EJMS Score (Overall Consensus)
Filling CO_2 containers (screwing lids with high torque forces)	Beverage bottling	85 (*1)	91 (*1)	102	100
Lifting product boxes (lifting large boxes above shoulder level)	Beverage bottling	55	58	55	55
Repairing pallets (using various hand tools, pushing pallets)	Beverage bottling	90	87	95	90
Opening and closing valves (rapid shoulder and arm movements)	Petroleum refining	71	64	65	65
Securing bolts on lids (using air impact gun)	Petroleum refining	45	51	48	45
Loading tablet coating machine (lifting drums)	Pharma. mfg.	61	65	74 (*2)	65
Manually filling cartons (repetitive hand & wrist motions)	Pharma. mfg.	55	56	61	55
Filling drums of tablets (repetitive bending at tablet press machine)	Pharma. mfg.	48	53	51	50
Palletizing boxes (transferring boxes from conveyor to pallet)	Pharma. mfg.	71 (*3)	75 (*3)	85	80
Lifting large size boxes at a printing area	Medical device mfg.	71	65	66	65
Manually assembling product (repetitive hand & wrist motions)	Medical device mfg.	49	55	55	55
Placing cartons onto pallets (repetitive bending to floor level)	Medical device mfg.	68	45 (*4)	65	65
Placing end plug on tube (repetitive motion with elbow)	Medical device mfg.	85	81	80	85
Lifting a 70-lb. railcar component from ground level	Railcar repair	79	85	86	84
Opening box car doors (manual pushing and pulling forces)	Railcar repair	85	92	91	90

Notes: **1 – Groups 1 and 2 underestimated static hand forces to hold heavier hand tools.*
**2 – CPE overestimated the degree of body twisting normally associated with this task.*
**3 – Groups 1 and 2 underestimated the degree of body twisting associated with this task.*
**4 – Group 2 underestimated both the lifting frequency and the hand distance at start of lift.*

said it was relatively easy to achieve team consensus by discussing risk factors, especially where individual scores varied by five or more points.

8) Team members reported that the system provided valuable information regarding key changes required to reduce overall risk level. Individual risk factors that received scores of 20, 15 and sometimes 10 were typically targeted for improvements.

CONCLUSIONS

EJMS has proven to be an effective tool in presenting risk assessment data to management. When used before and after a task is modified, it provides an objective method for documenting ergonomic improvements.

In addition, the score achieved provides a system whereby management can set priorities for corrective action. This allows management to allocate resources accordingly.

The EJMS process also considers business factors such as implementation time, estimated cost of improvement and projected impact on injury rates. The result is a cost-effective process for managing ergonomic risk mitigation activities.

Furthermore, the EJMS has proved to be an effective training tool. Team members share key observations regarding work postures, exertion levels, repetitions and other relevant ergonomic data as they reach consensus on each risk factor.

The value of any system is in measuring its effect on the organization. These effects have been positive with EJMS—leading to reduced frequency and severity of ergonomic-related injuries and illnesses. One industrial division of an international company has achieved a 50-percent reduction in WC costs, producing an annual savings of more than $2.5 million. While no ergonomic evaluation system is all-encompassing, the EJMS has been demonstrated to be a practical, results-oriented ergonomic risk assessment and risk management tool. ■

Authors' Note: The EJMS appears to correlate well with quantitative risk assessment and additional work is being done to validate whether the EJMS form is predictive of CTDs.

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David Ridyard, *CSP, CIH, CPE, is president of Applied Ergonomics Technology, Jenkintown, PA. Ridyard is a professional member of ASSE's Penn-Jersey Chapter and an elected member of AIHA's Ergonomics Steering Committee.*

Linda M. Tapp, *CSP, ALCM, is principal consultant and owner of Crown Safety, a safety, health and ergonomic consulting firm based in Cherry Hill, NJ. Tapp is a professional member and past president of ASSE's Penn-Jersey Chapter.*

Lawrence Wylie, *CSP, CIH, is corporate health manager with AHP, Parsippany, NJ. He is a member of ASSE's New Jersey Chapter.*

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