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4D WATBAK: Adapting Research Tools and Epidemiological Findings to Software for Easy Application by Industrial Personnel

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**4D WATBAK: Adapting Research Tools and Epidemiological
Findings to Software for Easy Application by
Industrial Personnel**

Human Factors Engineering Lab, Ryerson University

www.ryerson.ca/hfe

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For a more in-depth look on this subject, please see:

Norman, R., Wells, R., Neumann, W.P., Frank, J., Shannon, H. and Kerr, M., 1998. A comparison of peak vs cumulative physical work exposure risk factors for the reporting of low back pain in the automotive industry. *Clinical Biomechanics*, 13(8): 561-573.
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4D WATBAK: Adapting research tools and epidemiological findings to software for easy application by industrial personnel

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ABSTRACT

We have extended the research methods used in epidemiological studies of low back pain into assessment software that is suitable for use by industrial personnel. The system we are developing extends the capability of current biomechanical modelling approaches in two ways. We now have the ability to calculate shift-long cumulative loading (load integrals) on the spine as well the peak hand forces and peak spine load forces. We can also use epidemiological evidence to provide insight into low back injury risk in the presence of multiple, proven injury risk factors. This decision support aspect of the tool helps users apply current scientific evidence to make better decisions about job design and ergonomic program performance in industrial settings.

Keywords

Biomechanical models, physical load assessment, injury risk, low back pain

INTRODUCTION

We have recently completed a case-control study of biomechanical, psychosocial, psychophysical and personal factors that were suspected to be related to the reporting of low back pain in a very large automobile assembly facility (Norman et al. 1998). Cases (105) were those who reported LBP. Controls (130) were those who had not reported LBP in the preceding 90 days. Peak and cumulative biomechanical exposure of spinal structures to loading was obtained from direct observation and measurement and from video recording for up to a full shift in the workplace. The usual duration of recording of physical demands was 4 hours. A quasi-dynamic two-dimensional biomechanical model (WATBAK) was used as the primary spinal loading assessment method although a three-dimensional model was used from time to time as the nature of the task demanded. The other types of risk factors were obtained from interviewer-assisted questionnaires filled out by the workers in their homes. Several independent, statistically and functionally significant risk factors emerged. Independent biomechanical risk factors were: usual hand force, peak spinal shear, peak torso angle, cumulative spine compression over the course of a shift (Norman et al. 1998). Psychosocial risk factors were: adverse perceptions of workplace social environment and job control; positive perceptions of co-worker support, job satisfaction and relative education; a high rated-perception of the physical demands of the job; personal previous report of a compensation claim (Kerr et al. 1997).

Table 1: Independent Physical Loading risk factors for the reporting of low back pain

1. Peak Spinal Load
2. Cumulative Spinal Load
3. External (Hand) Forces
4. Trunk Kinematics

We have extended the research methods used in this study to create assessment software that is suitable for use by industrial personnel. A number of biomechanical models of varying levels of anatomical and functional complexity are available that can be used to assess low back tissue loads for a single instant of work. The models are typically two or three-dimensional static, dynamic or quasi-dynamic models of the lumbar spine that output estimates of physical loading on spinal structures. The system we are developing extends the capability of these kinds of programs in two substantial ways. We now have the ability to calculate shift-long cumulative loading (load integrals) on the spine as well the peak hand forces and peak spine load forces. We can also use the epidemiologic data to provide insight into low back injury risk in the presence of multiple, proven injury risk factors. This decision support aspect of the tool helps industrial personnel in their decision making about job design. The purposes of our paper are to demonstrate this software, explain the assumptions and data underlying the outputs and to obtain perceptions from participants in the session as to the viability of the approach.

METHOD

The 4D-WATBAK program includes both 2-dimensional and 3-dimensional link segment models. By allowing the user to enter work situations for multiple actions, and by accounting for the amount of time the worker spends performing each action, it is possible for the user to account for a fourth dimension, time, in their analysis. The ability to analyse multiple actions within a single assessment allows a more comprehensive approach to computerised load assessment. By accounting for all relevant actions in the target job the user can simultaneously account for peak spinal load, peak hand force, and cumulative spinal load per shift all of which have been shown to be independently associated with low back pain reporting.

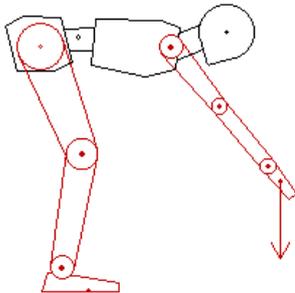


Figure 1: A sample posture screen

The first step in the assessment process to generate an inventory of relevant tasks and actions which are to be included in the assessment. The calculation of shift-long accumulated loading requires that the total time spent performing each action be included in the job description. Tasks that only occur for a very short proportion of the shift should still be included as they may be sources of high peak (instantaneous) loading. If the total of all action times does not add up to the full shift duration then all remaining time will be deemed “unaccounted for” and a nominally neutral (5 degrees flexed) posture will be assigned as the default loading condition. This is necessary to generate load integrals over a complete shift which are compatible with the epidemiological database.

Once the set of job actions and timings have been determined the observer can describe the specific instants of peak biomechanical load to be analysed. The posture for each action can be entered as a series of segment angles or the human mannequin can be manipulated directly with the mouse to achieve the desired posture (figure 1). Load amplitude and direction for each hand can also be entered (figure 2). This information, combined with the worker’s gender, height and weight, provide sufficient information for the biomechanical model to generate load estimates for the major body joints and especially the low back.

DATA PROCESSING

Model outputs include the moment of force (torque) demands at each body joint as well as the compression and shear forces at the lumbar (L4/L5) spine. The largest single value, observed across actions, is taken to be the peak load for each parameter. The cumulative (integrated) load for each parameter is then calculated using the time duration and amplitude for each action as well as the “unaccounted” for time and the loading associated with the default posture. The sum of these components across actions creates the shift total cumulative load.

The problem now is that the data obtained from such biomechanical exposure data generated by this approach is usable by scientists and other ergonomic specialists but is not suitable for use by plant personnel. If injuries are to be prevented or

if jobs are to be designed in ways that allow disabled workers to return to work then it is imperative that the plant personnel themselves be able to measure and interpret critical variables. While the system described so far allows relatively easy data collection the interpretation of the data remains problematic.

DATA INTERPRETATION

Estimates of risk of low back injury at work are often made by comparing the sizes of risk factors demanded by the job with limit values of these risk factors reported in the literature. An example of this

Figure 2: Hand force amplitude and direction input screen

“threshold limit value” approach is the NIOSH action or maximum permissible limit suggestions for spinal compression. This can be compared with the compression loads estimated for each action and a “pass/fail” type decision approach can be applied. This approach has been implemented in the current software (Figure 3) and is useful although the quality of the scientific evidence for the proposed limits, particularly the epidemiological evidence for spinal compression and the NIOSH AL, MPL or RWL, has been questioned. A further problem with the threshold approach may be the tendency of job designers to minimally reach the threshold rather than to design to minimise risk of injury.

Nevertheless comparisons to existing data provide a viable means of gaining insight on the physical demands of the job. One method of achieving this is to compare the strength demands of the job against measured population strengths. While there is still a need for better population capability databases a number of existing data sets have been incorporated in the existing model to provide users with a “percent of population NOT capable” of performing a given action (figure 4). While this information provides useful insight into job demands, especially for job design analyses, it does not necessarily provide direct insight into injury risk.

Spine Compression Limits

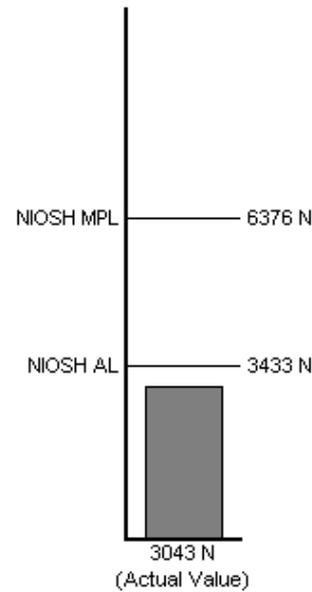


Figure 3: Spinal compression values can be compared to existing threshold limit values.

An additional problem is that risk of injury on any biomechanical

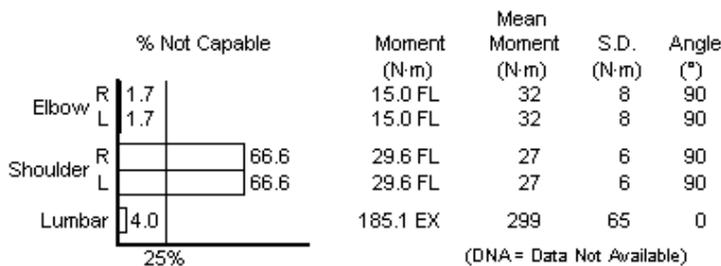


Figure 4: Joint strength demands can be compared to population capability.

Injury risk, on factors that have been shown to be related to some measure of risk (such as the reporting of LBP), might be more usefully presented as a probability rather than as a threshold limit value. Whatever one’s political perspective about the use of limit values to reduce risk in the workplace, at least presentation of the probabilities to potential decision-makers is useful. Our approach in the software has been to present all key LBP risk factors in terms of the associated probability of case classification. This assists the interpretation of exposures in terms related directly to injury risk and has the additional benefit of providing all variables in terms of a single metric which can simplify comparison and interpretation especially for managers and other non-specialists in ergonomics (Wells et al. 1996). The use of multivariable modelling techniques has allowed us to provide a combined probability estimate that simultaneously includes a

number of independent factors. This multivariable term has the same probability scale characteristics as the

variable that we have measured does not have a clear threshold limit value cut-off, below which people are protected and above which people are at risk. Figure 5 presents the classification curve resulting from logistic regression modelling of the peak spinal compression variable from the epidemiological study. The model indicates a continuing increase in probability of being classified a case as the exposure increases. Where then should the “threshold limit value” be set?

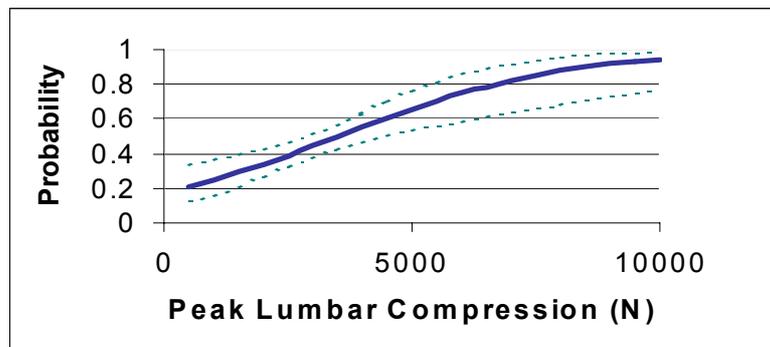


Figure 5: Statistical probability and 95% confidence intervals of lower back pain case classification as a function of peak lumbar compression.

univariable risk factors and can be interpreted in the same way (figure 6).

We believe the use of these performance indicators will enable industrial personnel to use current scientific evidence in their daily activities to prevent injuries in the work place. And that the ability of a company to successfully manage ergonomic processes in their operations depends on fast access to high quality information. With improvements in data collection and interpretation technologies it becomes feasible to consider the physical exposures

throughout the production system and not just in a single instant of a problematic job. This facilitates a pro-active anticipatory approach to injury prevention and allows exposure simulation and performance evaluations before expensive changes are implemented.

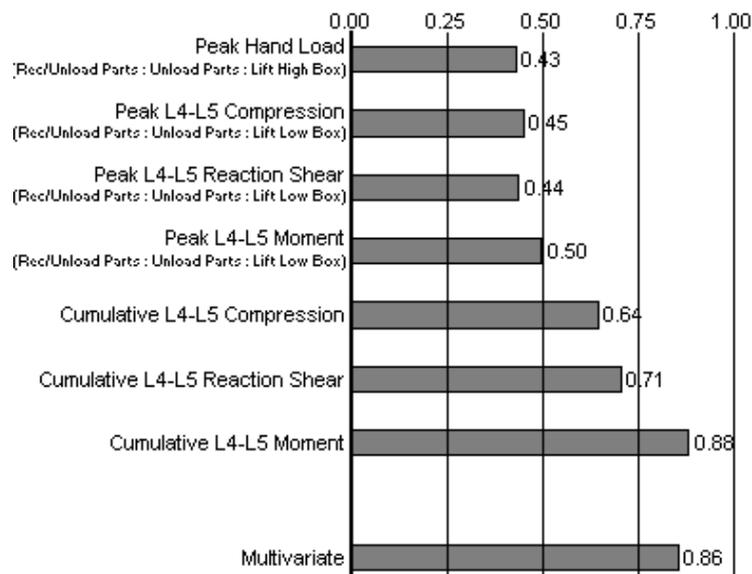


Figure 6: Epidemiological evidence is used to determine statistical probability of case-classification for individual and combined risk factors.

CONCLUSIONS

In extending our research methods into industry usable assessment tools we have focussed on three major avenues for improvement. The first is to use current graphical user interface approaches to facilitate the entering of posture and load data for biomechanical modelling. The second is to provide a structured task and action breakdown approach allows all aspects of a job to be included in the assessment. This results in estimates of shift-long accumulated loading – a proven independent risk factor for low back pain. The third aspect of consideration for the system was the presentation of the tools’ outputs in such a way as to support multiple users and ergonomics approaches from within the same analysis system. This includes detailed spine and body joint loading information for technical diagnostic work, comparison to existing threshold limit values for pass/fail assessment processes, comparison to population strength data for capability assessment, and comparison to epidemiologically generated statistical models for probability of case classification estimates. This kind of performance information is made accessible to non-specialists in ergonomics and facilitates the uptake and application of current scientific evidence in decision making affecting injury risk in the workplace. Our next step will be to apply and test this approach in an intervention research project in the industrial manufacturing sector.

ACKNOWLEDGMENTS

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Goals:

1. Develop the science of ergonomics
2. Develop Ergonomic tools and processes
3. Conduct education & training to support industry
4. Provide workplace analyses and consulting services

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Ontario Universities Back Pain Study

- University of Waterloo
- Institute for Work and Health
- University of Toronto
- McMaster University

STUDY PURPOSE

To identify the psychosocial and biomechanical risk factors for the reporting of low back pain.



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STUDY DESIGN: Case-Control

- 2 car and 1 truck assembly plants
- 10,000 hourly workers (production & non~)
- 2 main Groups
 - 104 Cases: People reporting Low Back Pain (includes 20 proxies)
 - 130 Controls: People without LBP reports
 - No LBP in previous 90 Days
- Incident Cases identified over 2 year period
- Both cyclic assembly and non-cyclic support work



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What was Studied?

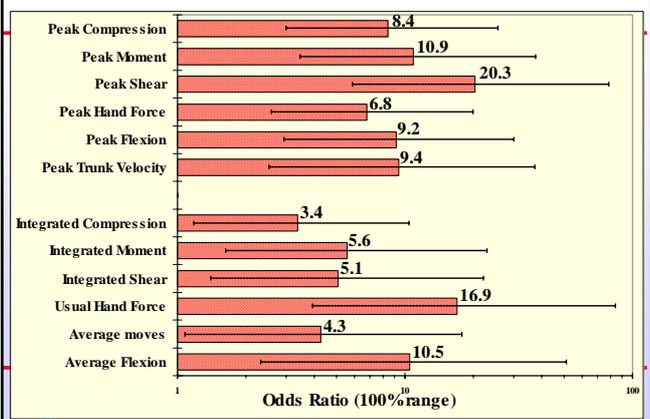
- **INDIVIDUAL:** Characteristics of the worker
- **BIOMECHANICAL:** objectively measured work demands
- **PSYCHOSOCIAL:** self-reported perceptions of the job and workplace environment



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Odds Ratios at Full Range



4 Biomechanical Factors

OUBPS Factor Analysis: (Norman et al. 1998 *Clin Biomech*)

1. Peak Spine Load
2. Integrated Spine Load
3. Trunk Kinematics
4. Hand Load

NIOSH 1997 Review:

- Lifting/Forceful Movement
- Heavy Physical Work
- Awkward Posture
- Whole Body Vibration



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4D WATBAK - Design Specs

GOAL: An easy to use implementation of the methods used in the OUBPS project for industrial users.

INPUTS - Action based job description Including

- ☑ Time, Posture, & Hand Forces

OUTPUTS - Presentation to accommodate multiple uses

- ☑ Peak & Cumulative biomechanical loads (raw)
- ☑ Compare to TLVs where available
- ☑ Comparisons to pop. strength capability
- ☑ Compare to epidemiological evidence



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Identify the job's component actions

Total Working Time / Shift	7:30:00	(h:mm:ss)		
Unaccounted Time / Shift	3:15:00	(h:mm:ss)		
	Reps.	Dur.	Total Time	
Demould				Add Task Group
Pull Foam				Add Task
2 hand Pull High Lid Foam	1440	0:02	0:48:00	Add Action
1 hand Pull High Lid Foam	1800	0:01	0:30:00	Add 3D Action
Pull Low Lid Foam	540	0:01	0:09:00	Remove
Pull Close Bowl Foam	4050	0:02	2:15:00	
Pull Far Bowl Foam	990	0:02	0:33:00	

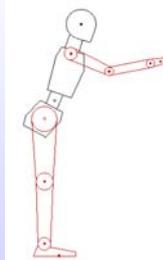


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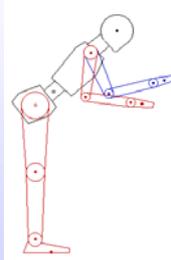
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Enter posture for each action

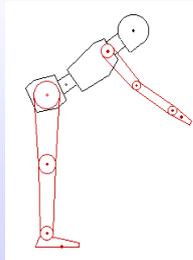
Pull high lid foam



Pull low lid foam



Pull far bowl foam



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Enter hand forces for each action

Magnitude: Total kg

LEFT RIGHT

Force Distribution: LEFT RIGHT

Direction of Force:

Lift Up Lift Up

Pull In Push Out Push Down

Pull In Push Out Push Down



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Look at exposure measures directly

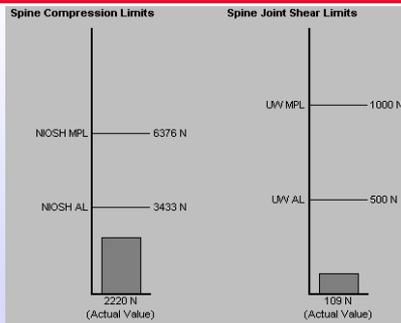
Peak Hand Load (Pull low lid foam)	117.7 N
Peak L4-L5 Moment (Pull far bowl foam)	118.4 Nm
Peak L4-L5 Compression (Pull far bowl foam)	2220.4 N
Peak L4-L5 Reaction Shear (Pull far bowl foam)	327.0 N
Peak L4-L5 Joint Shear (Pull far bowl foam)	161.7 N
Cumulative L4-L5 Moment	0.887 MNms
Cumulative L4-L5 Compression	24.867 MNs
Cumulative L4-L5 Reaction Shear	2.469 MNs



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Compare to Threshold Limit values



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Compare to Strength Capabilities

		% Not Capable	Moment (N-m)	Mean Moment (N-m)	S.D. (N-m)	Angle (°)
Elbow	R	0.1	3.5 FL	71	15	90
	L	0.1	3.5 FL	71	15	90
Shoulder	R	0.1	9.2 FL	53	13	90
	L	0.1	9.2 FL	53	13	90
Lumbar		25%	118.4 EX	480	93	0

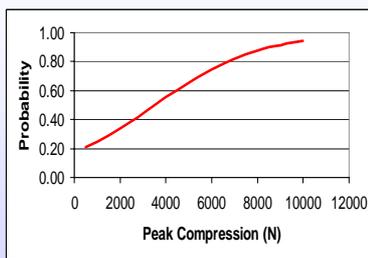
(DNA = Data Not Available)



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Exposure vs. Case Classification



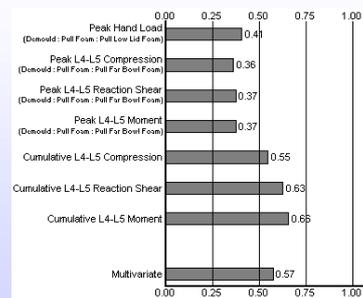
Statistical probability of case-group membership as a function of Peak Compression based on OUBPS data (Norman et al. 1998)



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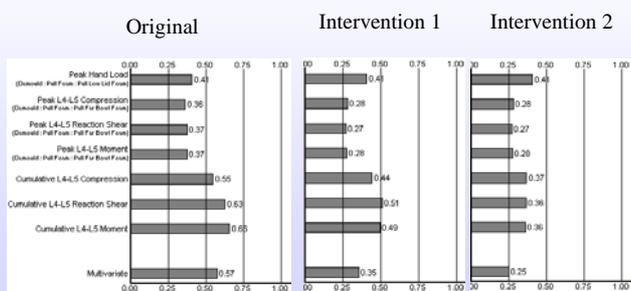
Compare to epidemiological evidence



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Test Interventions in Simulation



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Conclusions

- **4 Biomechanical LBP Risk Factors:**
 - Peak Spine Load, Cumulative Spine Load, Trunk Kinematics, Hand Forces
- **Methods implemented in usable software:**
 - Task Based Analysis includes times, postures, forces
- **Interpretation Available in terms of:**
 - Raw scores in real biomechanical units
 - Comparison to TLVs
 - Comparison to Strength Capability
 - Comparison to Epi Databases (classification probability)



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- Institute for Work and Health
- Workplace Safety and Insurance Board
- Ms. Amber Alpaugh is also recognised for her outstanding work in this project



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