Assessing Low Back Stress in the Construction Industry Using the Continuous Assessment of Back Stress (CABS) Method

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ASSESSING LOW BACK STRESS IN THE CONSTRUCTION INDUSTRY USING THE CONTINUOUS ASSESSMENT OF BACK STRESS (CABS) METHOD

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The construction industry has long been identified as a high risk industry for low back injuries due to the significant amount of manual materials handling and awkward trunk postures associated with many of its jobs. The variable nature of the tasks performed by construction workers expose these workers to risk factors for both acute and cumulative trauma injuries. The aim of this research project was to develop a modeling system that made use of existing assessment tools and probabilistic representations of low back stress. The results of this analysis are distributions of biomechanical stress that provide an appreciation for both the acute and cumulative trauma risks posed by these jobs.

INTRODUCTION

Job demands placed on construction workers include exposures to many recognized occupational risk factors for back pain including heavy work, materials handling, pushing, twisting, frequent lifting over 25 pounds, requirements for sudden unexpected maximal effort, and awkward, static postures (Bernold and Guler, 1993; Schneider, 1994). Unfortunately, models used to describe low back injury risk in traditional manufacturing environments (NIOSH Lifting Equations (NIOSH, 1981; Waters et al, 1993; Waters et al, 1994), The University of Michigan 3D Static Strength Prediction Program (3DSSPP™) and Lumbar Motion Monitor Model (Marras et al, 1993)) are limited in their ability to quantify the overall risk of construction industry jobs because they were not designed to address the highly variable biomechanical demands posed by these jobs. Further, construction industry jobs have risk factors for both acute and cumulative trauma injuries and existing models generally focus on one aspect of biomechanical loading. The LMM and NIOSH models are sound models for looking at repetitive manual materials handling (MMH) tasks and therefore address the issue of cumulative trauma well but are limited in considering acute trauma risks, while the 3DSSPP™ is well designed to consider acute trauma risk but is limited in assessing cumulative trauma risk. Our objective, therefore, was to build on these existing models to develop a probabilistic assessment tool that is able to assess overall biomechanical stress posed by jobs in the home-building industry.

METHOD

Subjects

Twenty-eight experienced construction workers were the subjects in this study. Fifteen of the workers were framers, eight were masons and five were drywall hangers. Workers from each of these trades were subsequently divided into sub-groups based on their primary work activities. These workers came from six different construction subcontractors and video data were collected on twelve different construction sites in the Raleigh-Wake County (North Carolina) area.

Data Collection

There were two phases of the data collection procedure in this study. The first was a collection of video footage of the activities performed by these workers throughout the workday. This entailed continuous video collection for multiple days on multiple sites for each of the three trades. Multiple cameras were used to monitor workers for the duration of each workday. The research team would arrive on the worksite the day the subcontractor began work on the house and followed them for the duration of their work on that house. The objective here was to obtain a valid sample of the work activities and biomechanical demands placed on the workers through all phases of the building process.

The second phase of data collection was a series of laboratory simulations. Using the results of the video footage as a guide, a list of fundamental trunk postures and motions observed on site was developed. Subjects then performed simulations of these work activities while wearing the Lumbar Motion Monitor. The subjects in these simulations were two 50th percentile (stature) males who were very familiar with the work activities to be simulated. All of the materials handled on the construction sites were used in the laboratory simulations. The subjects performed these work activities repeatedly, simulating the variability observed on the worksite. These kinematic data were used to drive the LMM risk assessment model. In addition to the trunk kinematic data, static, postural data (joint angles, 3-D moments of loads) were also obtained during these simulations and were used in the NIOSH and 3DSSPP™ models.

Data Processing

The video data collected on the construction sites were analyzed using a computer-based video coding system. The first step in this process was to imprint a time code on the video tape using a vertical interval time code generator. The analyst then processed the video tape by watching the tape and documenting changes in the work activity. The analyst documented the work activities by keying in a five character code describing the task being performed. (Tables 1-4 show the codes used in this analysis.) At the instant that the operator input the first character of the code, the computer sampled the time code off of the video tape and wrote it to an ASCII file. When the operator completed keying the five character code, this code was also written to the ASCII file. Using this approach the workers' activities were continuously described as were the duration of the individual activities. Some examples of the five character codes follow:

GF_G_ - person was holding a nail gun near ground level in front of their body

WLAB_ - person was lifting a brick at about waist level at 45° from the mid-sagittal plane

KPZ43 - person pushes a 12' length of 2' x 4' lumber at knee level, the push is outside of the mid sagittal plane and therefore generates a moment about the z-axis

The result of this coding process was an ASCII file that contained a series of five character activity codes and the corresponding time spent in each activity. These data were then processed in such a way as to render the total time spent in each 5 character codes during the construction of the house.

Table 1.
Hand Position (Code 1)

G - ground level
K - knee level
W - waist level
S - shoulder level
O - overhead level

Table 2.
Task (Code 2)

L - lift (or lower)
C - carry load on side
F - carry load in front
P - push (horizontal)
T - pull (horizontal)
I - pull (up at 45°)
O - push (up at 45°)
S - stand (unladen)
B - brick laying
K - block laying

Table 3.
Asymmetry (Code 3)

_ - none
A- asymmetric lift
Z- axial torque

Table 4.

Product Handled (Code 4)	Multiplier (Code 5)
G - Nail gun	No multipliers needed
R - Sledge hammer	
K - Caulk gun	
Z - Reciprocating saw	
B - Tar paper roll	
A - Pick ax	
R - Router	
T - Small hand tools	
J - Mixer pull-cord (masonry)	
S - Circular saw	
4 - 2 x 4	1- 4' length
6 - 2 x 6	2 - 8' length
8 - 2 x 8	3 - 12' length
1 - 2 x 10	etc.
A - Aluminum ladder	
L - LVL beam	
P - Plywood decking	1 - 2' x 4' section
C - Celotex Insulation	2 - 4' x 4' section
O - OSB sheeting	etc.
K - 1/2" Sheet Rock	1- per 54"x4'
Q - 1/4" Sheet Rock	1- per 54"x4'
T - Truss	(based on number of board feet of 2 x 4s or area of plywood)
W - Wall	
N - Nails	1 - 10 lb box
	2 - 20 lb box etc
G - Bag mortar mix	1 per 60 lb bag
B - Brick	1 per unit
C - Cinder block	
L - Brick cart	0=empty, 1=full
E - Mixer lever	0=empty, 1=full
X - Scaffold crossbars	1 per set
P - Scaffold plank	1 per section
S - Scaffold section	1 per section
P - Pail	0=empty, B=bricks,
W - wheelbarrow	M=mortar, S=sand
U - Tub for mortar	based on fullness
V - Shovel	0=empty, 1=full

For the LMM data, the processing entailed analysis of each of the data files to obtain the three kinematic variables that are needed to drive the risk assessment model: peak sagittal angle, peak lateral velocity and average twisting velocity. The other two important variables for this model (peak sagittal moment, lifting frequency) were derived from the video analysis and lab simulations.

Modeling

Using this 5 character activity code data, an estimate of low back stress was developed using four different assessment tools: 1) 3-D moments about the L5/S1 joint using 3DSSPP™, 2) the percent capable measure from the 3DSSPP™ model, 3) the lifting index from the 1993 Revised NIOSH Lifting Equation and 4) the probability of high risk group membership from the LMM model. Our method was to approximate the average technique (body posture, 3-D force vector at hands, trunk motion) used by the workers for each activity code and input these data into the models. Codes 1 and 3 established the position of the hands and posture of the torso, Codes 2 and 3 established the direction of the force vector and Codes 4 and 5 established the magnitude of the force vector. These data were used to establish a 3-D representation of the human for use in the NIOSH and 3DSSPP™ models. This process is illustrated in Figures 1 and 2.

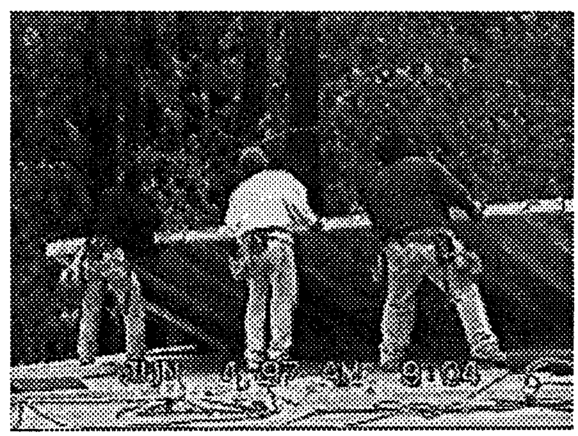

Figure 1. Framers lifting a wall.

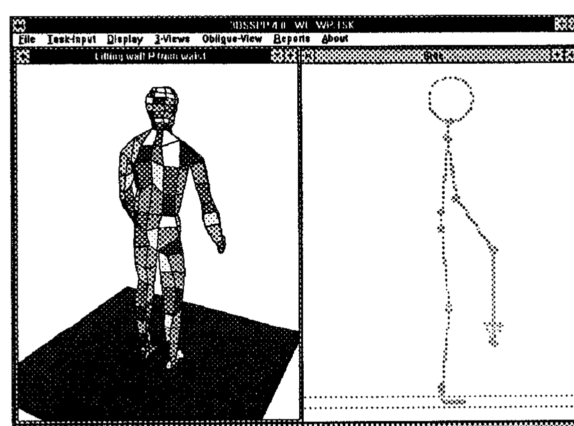

Figure 2. Three-dimensional representations of the activity shown in Figure 1.

RESULTS

The results presented here represent time spent in MMH activities. Eliminated from this analysis were the codes wherein the workers were standing upright, unladen (activities such as reviewing plans, walking, taking break etc.). While it is recognized that these "rest" breaks (particularly their temporal aspects) may hold important information regarding tissue recovery and ultimately back injury risk, our interests here are simply to document the biomechanical stresses and therefore they will not be considered.

Figures 3-8 illustrate the output that was generated from the biomechanical analysis. Figures 3-7 show the percent of the *time* spent at the different levels of the chosen measures of biomechanical stress while Figure 8 shows the percent of *exertions* at the different levels of probability of high risk group membership. Figures 3-5 show the moments about the x-axis (extension moment) for framers, drywall hangers, and masons, respectively. Figure 6 shows the y-axis (lateral bending) percent capable measure for the framers using the 3DSSPP™. Figure 7 shows the results from the NIOSH Lifting Equation analysis for the drywall trade. Figure 8 is a representation of the LMM model output for framers. Note that the different assessment tools represent biomechanical stress in a slightly different way thus allowing for a consideration of both the acute and cumulative trauma risks posed by these jobs.

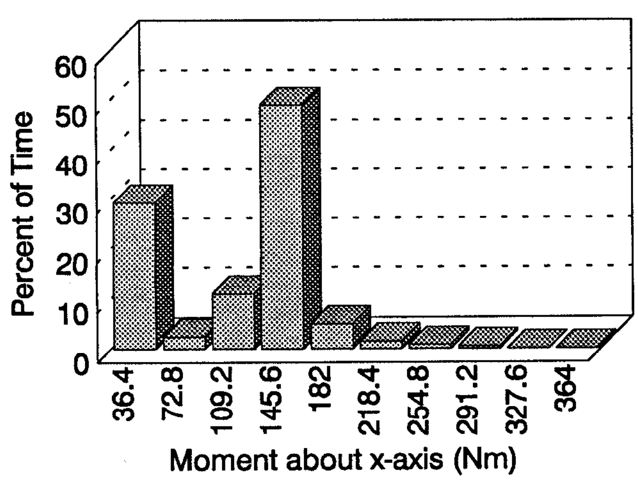

Figure 3. Percent of time spent at different levels of moment about x-axis (framers)

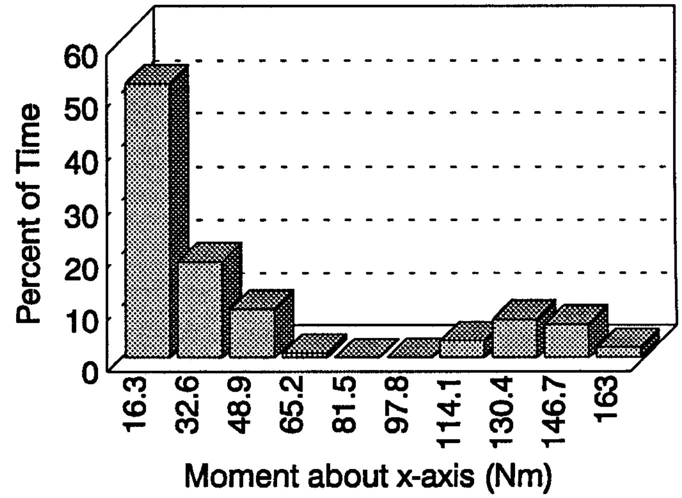

Figure 4. Percent of time spent at different levels of moment about x-axis (drywall hangers)

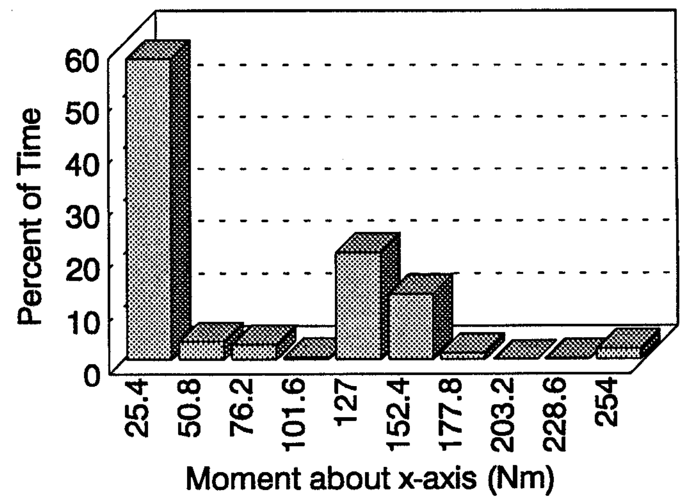

Figure 5. Percent of time spent at different levels of moment about x-axis (masons)

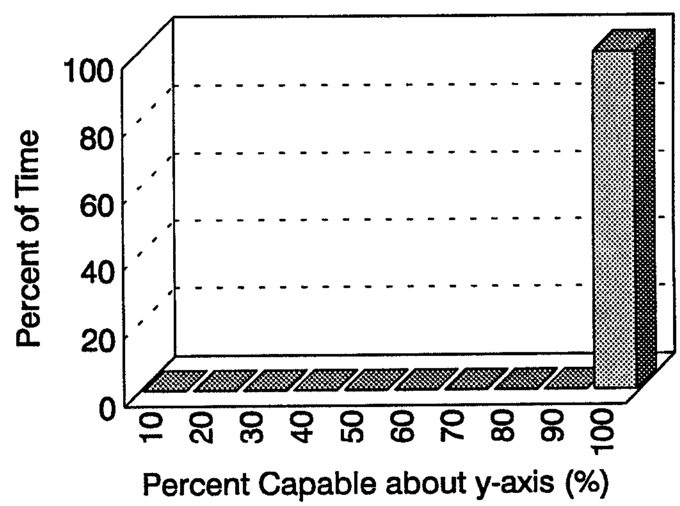

Figure 6. Percent of time spent at different levels of percent capable about y-axis (framers)

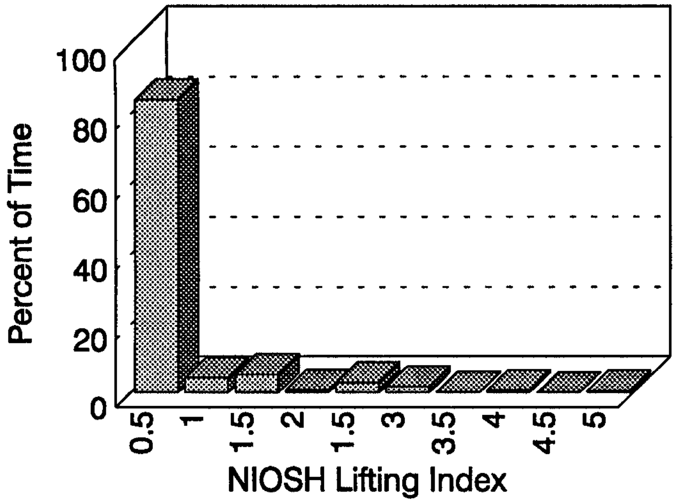

Figure 7. Percent of time spent at different levels of Lifting Index (drywall hangers)

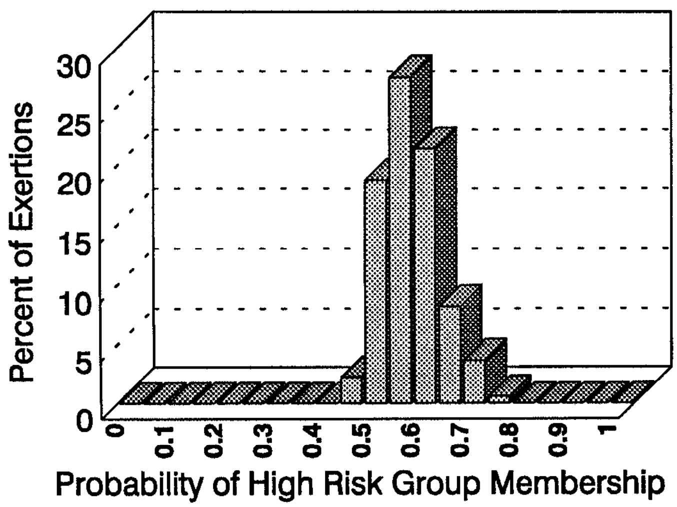

Figure 8. Percent of lifts at different levels of Probability of High Risk Group Membership (framers)

DISCUSSION

The technique described in this paper is part of a larger ergonomic intervention project for the home-building industry. In our review of existing assessment tools we noted some limitations of individual tools and considered the possibility of combining the strengths of these existing tools to document both acute and cumulative trauma risk. We also noted the tremendous variability present in these jobs and recognized the need for a probabilistic representation of the stresses. The distributions presented in this paper address both of these points. For example, note the peak in Figure 3 that occurs at about 145 Nm. Subsequent review of the raw data revealed that this peak was a result of work at or near ground level such as using a nail gun or saw or lifting light objects from ground level. Similar trends are seen in Figures 4 and 5 and represent a potential cumulative trauma risk. In addition, the right-hand tail of these distributions identify the infrequent, high stress exertions that are generally associated with acute trauma. These results have helped to focus our intervention efforts. This technique, while developed in the construction industry could be applied to virtually any industry where the demands placed on the workers are variable throughout the work day.

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