Proceedings of the Human Factors and Ergonomics Society Annual Meeting

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Proceedings of the Human Factors and Ergonomics Society Annual Meeting 2002 46: 1152
DOI: 10.1177/154193120204601331

The online version of this article can be found at:
http://pro.sagepub.com/content/46/13/1152

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Human Factors and Ergonomics Society

USE OF THE CABS METHODOLOGY TO ASSESS BIOMECHANICAL STRESS IN COMMERCIAL CRAB FISHERMEN

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Commercial fishing is a job characterized by long hours in an unpredictable natural environment and variable demands placed on the musculoskeletal system, requiring strength, coordination, and endurance. The focus of this project was in the quantification of the biomechanical stresses placed on the lumbar spine during the work activities of commercial crab fishermen. The Continuous Assessment of Back Stress (CABS) methodology was used to develop distributions describing the amount of time that each of the three workers on a three-man crabbing crew spend at various levels of spine stress. The results of this analysis, expressed in terms of time weighted histograms, show significant variability in the loading of the lumbar spine during regular daily activities both within and between crew members. While the captain has relatively low stress levels, the mate experiences high force (up to 30kg), dynamic exertions while pulling the crab pots from the water up into the boat and high loads (20-40kg) during the loading and unloading of the boat, while the third man experiences static awkward postures (forward flexed postures held for up to five minutes at a time) as he sorts and packs the crabs.

INTRODUCTION

Commercial fishing is a job characterized by long hours in an unpredictable natural environment. The work tasks demand strength, coordination, and endurance. There have been a number of studies that have focused on general safety issues in commercial fishing (e.g. Bull et. al., 2001; Jensen, 2000; Thomas et. al., 2001) but there have been surprisingly few investigating the ergonomic aspects of occupational fishing tasks (Fullmer and Buchholz, 2002).

One particular type of commercial fishing is commercial crab fishing. This is done in a number of ways, but one popular method is called crab pot fishing. In a three-man crab pot fishing crew there is a captain, a mate and a "third man". In this method of crab fishing, bait is placed in a 0.6m x 0.6m x 0.5m wire traps, known as "pots" which are thrown over the side of the boat and are attached with a rope to a buoy. These crab pots are laid in long lines and sit on the floor of estuarine waters. After a day of resting in that location and trapping crabs, the pots are retrieved by the crab fishermen who drives their boat along this line of buoys to retrieve their catch. In a three-man crew, the captain will drive the boat along the line of buoys and reach out with a hooked pole and snag the rope connecting the buoy to the pot. He will then pull the rope up to the side of the boat and then feed the rope into a device called a pot-puller, a mechanical device that will bring the wire pot up to the side of the boat. The second member of the crew, the mate, will then reach over the side of the boat and manually lift the pot up into the boat. He then opens the trap door and shakes all of the crabs out onto a sorting table, reloads the pot with new bait and throws the pot and buoy back overboard. The third crew member sorts out these crabs according to size and shell hardness. Each cycle (pot) takes about 30 seconds. In addition to these more cyclical activities that take place out on the water, there are activities that take place on shore before leaving in the morning (loading bait) and upon return at the end of the day (unloading the catch).

After reviewing some preliminary videotapes of these work activities, it was clear that there was a significant amount of variability in the loading patterns of the musculoskeletal system across work tasks, indicating that the Continuous Assessment of Back Stress (CABS) methodology (Mirka et al, 2000) (which was developed to characterize the biomechanical loading patterns in construction workers in the home building industry) would be an appropriate tool to represent the daily spine stresses.

The CABS method employs three well-established low back stress assessment tools (Revised NIOSH Lifting Equation (NIOSHLE) (Waters et al, 1993), University of Michigan Three-Dimensional Static Strength Prediction Program (3DSSPP) (Chaffin et al, 1987, 1991) and the Ohio State University Lumbar Motion Monitor Model (LMM) (Marras et al, 1993)) to quantify stress on a subtask by subtask basis. The output from this method are histograms describing the amount of time spent by the workers at different levels of stress. (Histogram of lifting index (NIOSHLI) from the NIOSH Lifting Equation, histogram of probability of high risk group measurement (PHRGM) from the LMM model and spine compression (3DSSPPC) from the Michigan model.) Our objective in this research was to use this methodology to quantify these biomechanical stresses experienced by the lumbar spine in an average day of commercial crab fisherman.

METHODS

Video footage was captured for a three-man crew engaged in crab pot fishing. This video was collected continuously and captured all of the work activities of each member of the crew throughout the workday. Using the CABS method, two aspects of the video data were captured in order to produce time-weighted histograms of back stress levels. First, each crewman's job was broken down into a series of subtasks. Analysis of the videotapes allowed for a temporal characterization of the amount of time spent in each of these subtasks. Second, three-dimensional stick figure models were constructed for each subtask and the biomechanical loads on the spine (compression, sagittal plane moment, coronal plane moment, transverse plane moment) were calculated. These stick figure data were then used to approximate the input variables of the NIOSH Revised Lifting Equation. Finally, each of these subtasks were performed in the laboratory using the Lumbar Motion Monitor to capture the necessary input variables to the OSU LMM model. Using the temporal information from the video analysis along with the output measures from each of the three risk assessment models, histograms of percent time at different levels of spinal stress assessments were generated.

RESULTS

Twenty-eight different subtasks were identified in the CABS analysis of a 3-man crabbing operation. Averaged across crew members, the fishermen spent 65% of the work day in upright, unloaded tasks such as upright standing, driving the boat, walking on deck, sitting, etc. These tasks involved little or no external loads and no significant trunk motion. The rest of the time involved some sort of manual material handling activity.

The results from the CABS analysis show stark contrasts in the assessments of the stress posed by these different work activities (Figures 1-3). Figure 1 shows the histogram of the NIOSHLI measure summed across crew members. Similarly, Figures 2 and 3 show the 3DSSPPC and PHRGM measures, respectively. All histograms show the these distributions for these measures with the 65% "unloaded" time excluded. It is interesting to note that percent of time spent at low levels of NIOSHLI was quite high and this is due to the light hand-held loads by these workers. The PHRGM and 3DSSPPC, in contrast, have a much more negative view of this work because of the static awkward postures (3DSSPPC) and dynamic nature (PHRGM) of these tasks.

To further refine these analyses and highlight the specific areas ripe for ergonomic intervention, similar histograms were developed for each crew member. Because of space considerations, only the data for the 3DSSPPC (Figures 4-6) and PHRGM (Figures 7-9) are presented in this paper. These figures illustrate the considerable inter-individual differences present between the different classifications of workers on the commercial crab fishing crew.

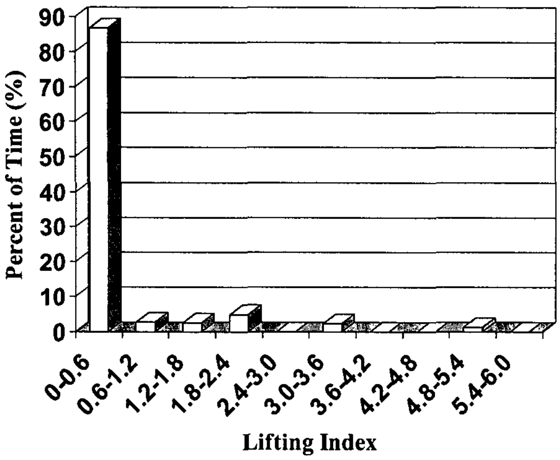

Figure 1. Histogram of the NIOSHLI measure averaged across the three-man crew.

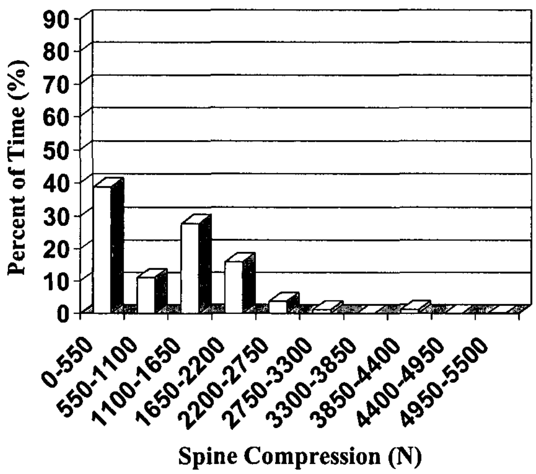

Figure 2. Histogram of the 3DSSPPC measure averaged across the three-man crew.

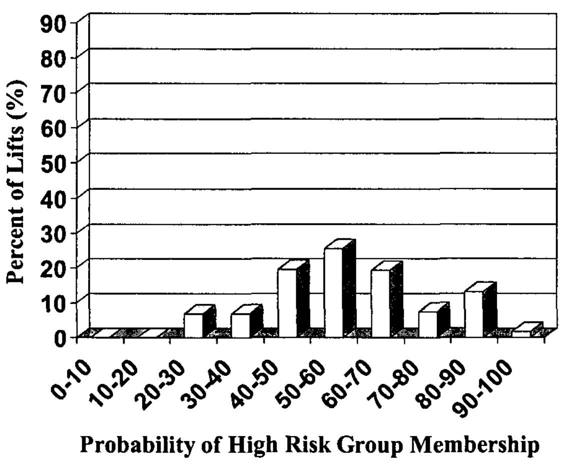

Figure 3. Histogram of the PHRGM measure averaged across the three-man crew.

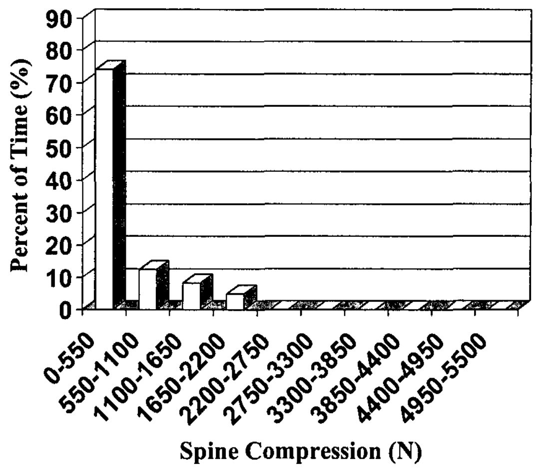

Figure 4. Histogram of the 3DSSPPC measure for the captain.

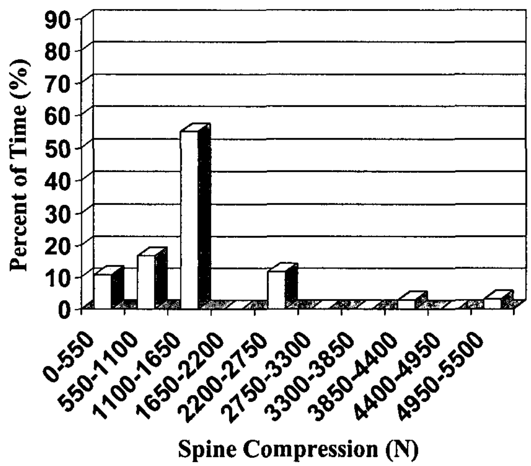

Figure 5. Histogram of the 3DSSPPC measure for the mate.

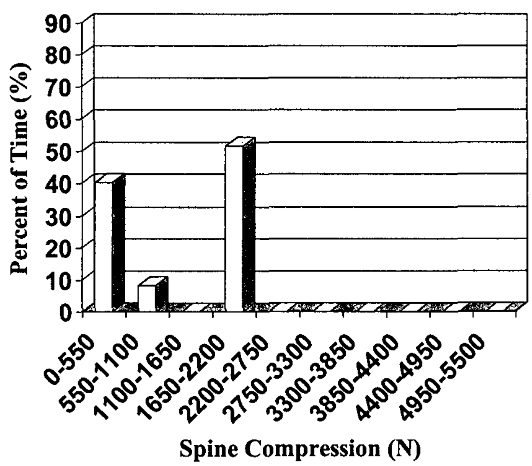

Figure 6. Histogram of the 3DSSPPC measure for the third man.

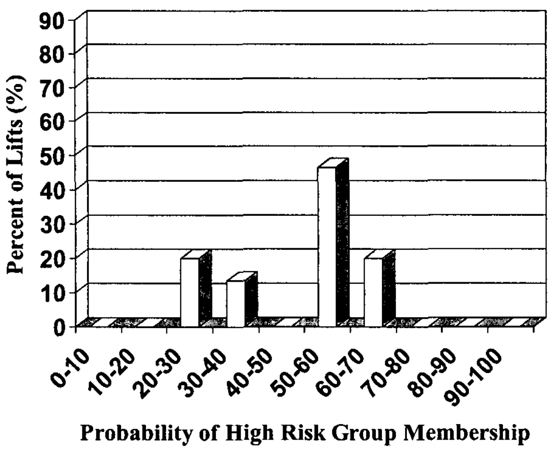

Figure 7. Histogram of the PHRGM measure for the captain.

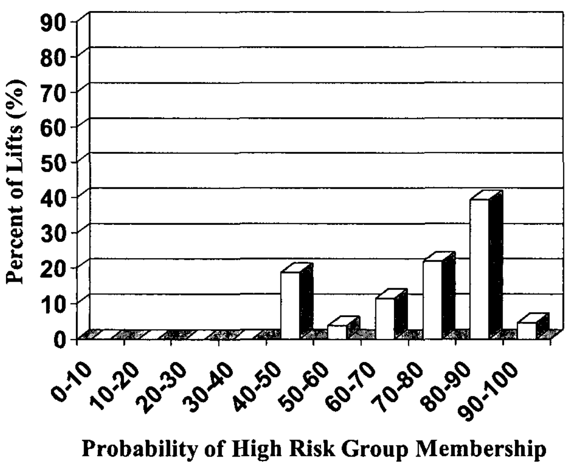

Figure 8. Histogram of the PHRGM measure for the mate.

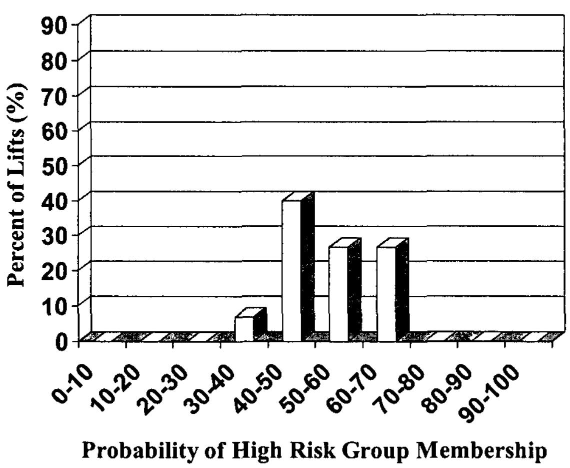

Figure 9. Histogram of the PHRGM measure for the third man.

DISCUSSION

The logic behind the CABS methodology revolves around two main concepts. First, that each of the well-established risk assessment tools employed in the model consider the risks posed by physically demanding work from different perspectives. The NIOSH model performs best when significant hand held loads are present, the LMM model performs best when trunk dynamics are involved and the 3DSSPPC is very sensitive to awkward postures of the torso. The second concept is that many jobs have considerable variability in the physical demands posed and that this variability needs to be characterized in order to fully appreciate the acute and cumulative biomechanical stress posed by the work activities. This modeling approach proved very valuable in our ergonomic intervention research for the home building industry (Mirka et. al., 1998; 2000a,b). Therefore, one of the goals of this research was to evaluate this modeling approach in tasks other than those for which it was originally developed. The other main objective of this work was to characterize the stresses experienced by these so that high risk tasks could be identified for future ergonomic intervention activities.

Activities found most biomechanically stressful for the lumbar spine were manual materials handling such as lifting and carrying 20kg baskets filled crabs during unloading at the end of the day and lifting and lowering 40kg totes of frozen bait during morning preparations. These MMH activities collectively represented 14% of the workday and produced a maximal moment of 338 Nm and 5230N of spinal compression.

Other interesting results of this analysis were the differences found between the biomechanical loads experienced by the different crew members. These results showed that the captain experienced relatively low loads throughout the workday. One characteristic that was consistent for this position was that his torso was in an upright posture most of the day (Figure 4). Driving, hooking the buoys, pulling the buoys to the pot-puller all allowed him to maintain an upright and neutral posture. The mate, on the other hand, experiences high force (up to 30kg), dynamic exertions while reaching over the side of the boat to pull the crab pots from the water up into the boat (Figure 8). The mate is also heavily involved in the process of loading the bait onto the boat in the morning and unloading the catch at the end of the day. The nature of the loads experienced by the third man were characterized by long duration static postures during the sorting and packing of the crabs (Figure 6).

The results of the analysis of these work tasks using the CABS methodology revealed information important to establishing potential high risk activities for lumbar spine injury. This technique revealed a high degree of variability both within and between subjects. By representing these biomechanical stresses using time-weighted distributions we can gain an appreciation for both the acute and cumulative risks posed by these work activities. This distinction is most prominent in comparing the work activities of the mate and the third man of the crew. For the crew that we sampled the mate was responsible for the loading of bait and the unloading of the crabs at the end of the day. These were clearly the highest risk activities for acute injury due to the high loads observed. The third man on the other hand, maintained awkward forward flexed postures for extended periods of time indicating a different kind of stress. These distinctions are illustrated by the peak compression values for the mate (up to 5000N) and the large percent of time spent at spine compression values of ~1800N for the third man.

As opposed to more traditional manufacturing environments, environment plays a major role in the risks to the musculoskeletal system. First, much of the manual materials handling is done on the water, leading to unstable and slippery footing, shifting loads (both hand held and body mass loads) and uncontrolled and unfavorable weather conditions (heat, cold, humidity, wind, etc.) For those tasks that are performed on land they are either undertaken first thing in the morning when the muscle have not had adequate warm-up or in the evening when the muscles are fatigued. Characterization of these occupational stresses can aid in identification of musculoskeletal injury risk for fishermen and help in developing appropriate interventions.

ACKNOWLEDGEMENTS

This work was supported by Grant No. R01- OH04073 from the National Institute for Occupational Safety and Health (NIOSH). The contents are solely the responsibility of the authors and do not necessarily reflect the views of NIOSH.

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