THE RELATION BETWEEN FREQUENCY OF INDUSTRIAL LIFTING AND THE FATIGUE PRODUCED

Matthew London and Amit Bhattacharya*

National Institute for Occupational Safety & Health
5555 Ridge Avenue-Cincinnati, Ohio 45209
Department of Environmental Health
University of Cincinnati
Cincinnati, Ohio 45267-0056, U.S.A.

Four industrial lifting jobs were analyzed using the National Institute for Occupational Safety and Health's (NIOSH) Work Practices Guide for Manual Lifting. One repetitive lifting task was selected for laboratory simulation. The objectives were to determine if the fatigue produced was related to the lifting frequency, and to test the NIOSH Guideline's ability to predict a lifting task's stressfulness. The task involved lifting and lowering 4.08 kg in the sagittal plane, using both hands. Twelve male non-industrial subjects were required to lift for 30 min at each of 3 lifting frequencies (2, 6, and 10 lifts/min). Fatigue was estimated using parameters of heart rate, maximum voluntary contractions for grip, arm, and torso strengths and Borg's Rating of Perceived Exertion (RPE) scale. NIOSH's guideline was found to be a good predictor for this task.

Lifting at the low frequency was easy to sustain for all subjects. Lifting at the moderate frequency produced symptoms of fatigue approaching, yet below, accepted benchmarks. Lifting at the high frequency was unduly stressing to most subjects, and was assumed to increase the risk of injury if continued at that pace. Finally, the study's significance relative to the common practice of paying workers on a piece rate is discussed.

In the United States it has been estimated by the National Safety Council that 15% of all workers' compensation claims are for low back injuries. These claims amount to over $1 billion per year, yet payments account for less than 1/3 of the wage earning capabilities of the workers (NIOSH, 1981). When one considers both lost work time and medical expenses attributed to occupational low back pain and related musculoskeletal conditions, the total annual cost rises to in excess of $14 billion in the United States (Habes, et al., 1983). Thus, the subject of manual materials handling-induced back injuries has warranted continued in-
terest by researchers.

The National Institute for Occupational Safety and Health (NIOSH, 1981) has created a mechanism by which all two-handed sagittal lifting jobs can be evaluated. It combines epidemiologic, biomechanical, physiologic, and psychophysical approaches into one equation:

\[
AL(kg) = 40\left(\frac{15}{H}\right)(1-0.004V-75)(0.7+7.5/D)(1-F/F_{\text{max}})\text{ metric units (1)}
\]

where

\[H=\text{horizontal location forward of midpoint between ankles at origin of lift (cm)},\]
\[V=\text{vertical location at origin of lift (cm)},\]
\[D=\text{vertical travel distance between origin (cm), and destination of lift},\]
\[F=\text{average frequency of lift (lifts/min)},\]
\[F_{\text{max}}=\text{maximum frequency which can be sustained; obtained from NIOSH work practices guide book (NIOSH, 1981)}.\]

\[
MPL=AL\times 3\text{ (2)}
\]

In the above equation when the weight to be lifted, horizontal distance of the load from the body, vertical location of the load at origin, vertical travel distance of the lifts, and lifting frequency are all inserted, the lifting job can be classified in one of three ways: below the Action Limit (AL)-safe for most people; between the AL and the Maximum Permissible Limit (MPL)-in need of administrative or engineering controls; or above the MPL-engineering controls required.

The present study was undertaken to examine the role that frequency of lift plays in the development of whole-body fatigue during a study of a manual materials handling task simulation of an actual industrial job. Physiologic and psychophysical tests which measure symptoms of fatigue were chosen for this. The implication of the results on the wide-spread industrial practice of piece work incentive are briefly discussed.

**METHODS**

A local factory in which a number of manual materials handling tasks are performed was selected for study. Four jobs which involved repetitive lifting were subjected to analysis using the NIOSH equation (1). One task was then selected for laboratory simulation. This task was one of two which exceeded NIOSH's AL and was the only pure lifting job-i.e., not involving machining of parts which would complicate the use of NIOSH's formula and make simulation more difficult.

**Subjects.** Twelve males between 21 and 34 years of age (mean 27.8±4.3) served as volunteers for the laboratory lifting task. Each had some previous industrial lifting experience, though none were employed as laborers at the time of the experiment. Each subject attended an orientation session where the lifting task and the fatigue tests were demonstrated. Each subject was also prescribed a seven-day exercise regimen to strengthen and condition back and abdominal muscles.
Table 1. Demographic characteristics of Subject population (number of subjects = 12).

<table>
<thead>
<tr>
<th></th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>27.8±4.3</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>182.7±6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>80.6±8.2</td>
</tr>
<tr>
<td>Forearm-hand length (cm)</td>
<td>50±2</td>
</tr>
<tr>
<td>Hand length (cm)</td>
<td>20±0.9</td>
</tr>
<tr>
<td>Hand width (cm)</td>
<td>9.1±0.6</td>
</tr>
</tbody>
</table>

The details on the subjects’ anthropometric measurements are given in Table 1. The anthropometric measurements were made according to the terminology used previously (HERTZBERG et al., 1954).

Approval from University of Cincinnati’s Human Subjects Review Committee was obtained.

Task. The job selected for laboratory simulation was a pure repetitive lifting task. In the factory it involved removing metal parts from one bin and placing them in an adjoining bin (Fig. 1a, 1b). The parts were not machined or otherwise handled during this operation.
In the laboratory a work station was constructed which replicated the dimensions and layout of the factory job (Fig. 1c, 1d). The station consisted of two tables, each 40 cm high, each with an empty crate (33 cm long and wide, and 28 cm high) on top. The center of each crate was 69 cm in front of (horizontal distance) the subject. This horizontal distance was measured from a point midway between the subject's ankles, as prescribed by the NIOSH (1981) method. The centers of each crate were 122 cm apart, and there was a barrier 85 cm above ground level which was placed between the two crates, assuring that the weight was lifted to the appropriate height.

Ten lead-filled plastic cylinders were used. Each cylinder was 27 cm long, with diameters of 5.7 cm at one end and 6.3 cm at the other. Each weighed 4.08 kg. The cylinders were initially placed in one crate. The subject would then remove the cylinders at a prescribed frequency for a period of 30 min. The task was paced by a pulsing light and buzzer which signalled simultaneously. Upon receiving a signal the subject would stand with his feet touching a mark on the floor, and would lift one cylinder in a two-handed sagittal manner. The cylinder would be brought to forearm length in front of his torso and carried over the 85 cm barrier. He would then move his body to the mark which was in front of the second crate, and would place the cylinder in that crate. He could then stand in any position until the next lift was signalled. Once 10 lifts had taken place and all ten cylinders has been placed in the second crate, the subject then would proceed by moving the cylinders in the opposite direction, as paced by the pulsing light and buzzer. This continued for 30 min.

Experimental procedure. Each subject performed the experiment beginning between 10:30-11:00 a.m. so as to minimize circadian rhythms as a confounding factor.

Before lifting began, maximal isometric strengths of 3 muscle groups were obtained. Torso lift and arm lift were performed in accordance with the guidelines issued by the American Industrial Hygiene Association (AIHA), Committee on Ergonomics (1971). The posture for the torso lift was chosen to approximate the median vertical and horizontal origin of the lifting task. The handlebar, which was isometrically pulled, was attached via steel cable to a load cell (Interface Inc., model SSM-NS-1000). The force exerted was then recorded on a strip chart recorder (Gould Industries, Inc., model 2600). For the two-handed arm lift the position of the handlebar was adjusted so that the subject's forearms would be parallel to the ground. Grip strength was measured using a hand grip dynamometer. The subject was instructed to use his preferred hand and to keep his arm hanging at his side. He was asked to adjust the grip span of the dynamometer until he felt it was set so as to allow him to exert his maximum voluntary contraction without jerking. A total of three trials for torso and arm lift and grip strength were obtained, the mean value of which was considered to be the baseline maximum voluntary contraction (MVC).
After completion of the baseline strength measurements, the subject was then fitted with a heart rate monitor with a digital display (Respironics, Inc., Exersentry III model). Borg's Rating of Perceived Exertion (RPE), to be administered immediately post-lift, was then explained.

Meanwhile, the subject was kept seated for at least 10 min to obtain a resting heart rate. The resting heart rate was considered to be the mean value of the heart rate for the last 3 min. For analysis purposes, work pulse was defined as peak minus resting heart rate.

The subject was then told to perform the lifting task. A total of 3 lifting sessions were undertaken for each subject, all during the same day. Each session lasted 30 min, during which time the subject lifted at a constant frequency. Each session was performed at a different lifting frequency, the order of which was randomized. The 3 frequencies were 2, 6, and 10 lifts per minute.

During each lifting session, heart rate was transcribed from the digital display once each minute. Upon completion of the 30 min of lifting the subject was told to immediately rate his exertion for that session on the RPE scale. He was also asked if he experienced any pain ("Where do you hurt the most, if anywhere?") and if he could have lifted at that frequency for a full hour ("Could you lift at this pace for 1 hr without excessive fatigue?"). He then immediately performed an MVC for grip strength, torso lift, and arm lift, respectively. All post-lift testing took no more than a total of 2 min to conduct. The subject was given 45 min' rest between lifting sessions. Resting heart rate was again obtained during the last 10 min of the rest period.

Data analysis. Statistical analysis of data involved calculation of means, standard deviations, t-tests, Neuman-Keuls' multiple range test, linear regression correlation and Spearman Rank correlation.

RESULTS

Four factory jobs were analyzed according to the NIOSH equation (1) (Table 2). The 'impregnator' job or task #4 was the only one which was significantly above the AL, implying the need for administrative or engineering control. The results for the laboratory simulation of Task #4 follow.

Cardiovascular response

The summary heart rate data from all twelve subjects are presented in Table 3. Relative to the resting pulse, the heart rate increased: 40.5% while lifting 2 times/min; 46.5% during 6 lifts/min; and 79.2% at 10 lifts/min.

The Newman-Keuls test was used to compare the work pulse at all 3 lifting frequencies. The work pulse at 10 lifts/min was different from the work pulse at either 2 lifts/min or 6 lifts/min ($p<0.01$). The work pulses at two and 6 lifts/min did not significantly differ from each other ($p>0.05$).
Table 2. Summary of factory job analysis.

<table>
<thead>
<tr>
<th>Job name at the factory</th>
<th>$H$ (cm)</th>
<th>$V$ (cm)</th>
<th>$D$ (cm)</th>
<th>$F$ (lifts/min)</th>
<th>$F_{\text{max}}$ (lifts/min)</th>
<th>AL (kg)</th>
<th>$M^*$ (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Job 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Camlock&quot;</td>
<td>63.5</td>
<td>53.3</td>
<td>40.6</td>
<td>0.3</td>
<td>12</td>
<td>7.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Job 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;6-Spindle&quot;</td>
<td>86.4</td>
<td>121.9</td>
<td>68.6</td>
<td>9.5</td>
<td>15</td>
<td>1.8</td>
<td>0.05</td>
</tr>
<tr>
<td>Job 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Drill &amp; Tap&quot;</td>
<td>66.0</td>
<td>53.3</td>
<td>25.0</td>
<td>0.5</td>
<td>15</td>
<td>8.3</td>
<td>8.8</td>
</tr>
<tr>
<td>Job 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Impregnator&quot;</td>
<td>68.6</td>
<td>50.8</td>
<td>25.0</td>
<td>6.2</td>
<td>12</td>
<td>4.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

For details of $H$, $V$, $D$, $F$, $F_{\text{max}}$, AL, see eq. (1).

$M^*$ = average mass lifted for the task in the factory.

Table 3. Cardiovascular response: heart rate data at three lifting frequencies.

<table>
<thead>
<tr>
<th>Lifting frequency</th>
<th>Resting pulse</th>
<th>Work pulse</th>
<th>Peak pulse</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/min</td>
<td>70.2±8.1</td>
<td>28.4±8.5</td>
<td>98.6±14.4</td>
<td>$p &gt; 0.05^*$</td>
</tr>
<tr>
<td>6/min</td>
<td>69.9±9.1</td>
<td>32.5±7.9</td>
<td>102.4±15.0</td>
<td>$p &lt; 0.01^{**}$</td>
</tr>
<tr>
<td>10/min</td>
<td>67.2±6.4</td>
<td>53.2±14.0</td>
<td>120.4±18.7</td>
<td></td>
</tr>
</tbody>
</table>

* Work Pulse at two and 6 lifts/min not significantly different from each other.

** Work Pulse at 10 lifts/min significantly different from that at either of the other two lifting frequencies.

Resting pulse not significantly different prior to each lifting frequency, $p > 0.05$.

Table 4. Muscle strength response.

<table>
<thead>
<tr>
<th>Lifting frequency</th>
<th>Grip strength</th>
<th>Arm strength</th>
<th>Torso strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>50.9±8.2</td>
<td>29.9±10.8</td>
<td>63.9±24.4</td>
</tr>
<tr>
<td>2/min</td>
<td>49.9±8.7</td>
<td>32.0±10.1</td>
<td>59.9±28.9</td>
</tr>
<tr>
<td>6/min</td>
<td>50.2±7.9</td>
<td>30.6±10.2</td>
<td>55.4±24.5</td>
</tr>
<tr>
<td>10/min</td>
<td>50.2±8.0</td>
<td>31.9±10.6</td>
<td>62.2±24.2</td>
</tr>
</tbody>
</table>

$p > 0.05$ for each of the three strength tests: grip, arm, and torso.

Muscle fatigue

The mean values for each strength test, obtained prior to any lifting session, are presented in Table 4.

Relative to the baseline values, grip strength decreased slightly after each of the lifting sessions. When comparing the baseline and post-lift grip strengths with each other, none were found to be statistically different ($p > 0.05$). Therefore,
Table 5. Estimation of fatigue by psychophysical response.

<table>
<thead>
<tr>
<th>Frequency of lift</th>
<th>Borg's RPE</th>
<th>number of subjects=12</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/min</td>
<td>7.7±1.6</td>
<td>12.8</td>
</tr>
<tr>
<td>6/min</td>
<td>10.8±1.7</td>
<td>9.5</td>
</tr>
<tr>
<td>10/min</td>
<td>15.2±1.9</td>
<td>7.9</td>
</tr>
</tbody>
</table>

frequency of lift did not have a significant effect on grip strength.

Two sets of maximum isometric lifting strength tests were undertaken; two-handed arm strength and torso strength. Arm strength increased relative to the baseline value after each lifting frequency. However, when mean arm strength was compared under all four test conditions (baseline, and after the 3 repetitive lifting sessions), no significant differences were found (p>0.05) (Table 4).

Torso strength decreased after all three lifting sessions when compared to the baseline value. However, when compared with the baseline strength, and with each other, the differences were not significant (p>0.05).

There was great variability in the strength test results, particularly for the arm and torso strengths (Table 4). The overall coefficient of variation was 16.3% for grip strength, 33.5% for arm strength, and 42.2% for torso strength. The high variability of arm and torso strengths existed for intra-subject as well as inter-subject results.

Perceived fatigue

Ratings of Perceived Exertion (Borg’s RPE Scale) did vary with the frequency of lift. Each set of RPE values differed significantly (p<0.01), from the other 2 sets obtained (Table 5). There was low variability in the results, particularly when compared to the strength tests. For each subject, the RPE value selected increased with the increasing lifting frequency.

Each subject was also asked to assess his own fatigue and discomfort by answering the two questions indicated in the METHODS. After lifting twice/min, all twelve subjects said they experienced no pain. After 6 lifts/min, ten subjects had no pain, one had some shoulder pain, and one had some pain in the mid-back area. After 10 lifts/min only two subjects felt no pain, 5 had pain in the lower-back, one in the lower-back and forearm, one in the lower-mid back and three in the mid-back. Also, after both 2 lifts/min and 6 lifts/min all 12 subjects said they could lift for a full hour. However, only 5 subjects said they could lift for a full hour at 10 lifts/min.

Relationships between perceived fatigue and other indicators of fatigue

When comparing RPE versus the work heart rate a correlation coefficient, r, of 0.572 was obtained. The students’ t-test found this to be significant, p<0.005. The Spearman Rank Correlation also indicated a statistically significant relation-
ship between RPE and work heart rate, $p<0.002$.

Comparing RPE with each of the three strength parameters, no significant correlation was found.

DISCUSSION

Before assessing the various fatigue parameters, a comparison of the lift conditions in the laboratory with those in the factory should first be performed. The major task parameters of $H$, $V$, $D$, $F$, and mass were nearly identical in the laboratory and factory (Table 6). The demographic characteristics of the task operators were similar in the laboratory and factory. A potential difference is that the laboratory subjects were not as well conditioned to the task, having only performed a moderate one-week exercise regimen. Therefore their response to the task is probably best compared to a newly assigned operator in the factory. Beyond that the response to the laboratory simulation should mimic and predict the actual response occurring in the factory.

The mean peak heart rates which resulted from lifting frequencies of 2, 6, and 10 lifts per min were 98.6, 102.4, and 120.4 beats per min (BPM) respectively. The AIHA’s Ergonomics Guide (1971) gives a pulse rate of 90–100 BPM as a typical 8-hr rate for physically active workers. Few men work at a pace producing a pulse of 110–120 BPM. Pulses of 120–130 BPM are acceptable for a maximum of 1 hr. This indicates that performing this specific lifting task at 10 lifts per min is acceptable only for a short duration. A pace of 6 lifts per min is marginally acceptable for a full work shift. These observations are confirmed by other researchers. Snook (1978) suggested that activities which produce heart rates greater than 115 BPM are excessively fatiguing. Grandjean (1980) used work pulse as a fatigue indicator. According to his study a work pulse value of 35 BPM should not be exceeded. The work pulses for our three work loads were 28.4, 32.5, and 53.2 BPM, indicating lifting 6 times per min to be marginally acceptable, while 10 lifts per min produced excessive fatigue.

The above guidelines of the AIHA, Snook, and Grandjean all indicate that lifting 2 times per min did not produce excessive cardiovascular stress. Astrand and Rodahl (1977) categorized work according to the heart rate produced. Ac-

<table>
<thead>
<tr>
<th>Task parameters</th>
<th>Laboratory simulation</th>
<th>Impregnator (factory job)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H$ (cm)</td>
<td>69</td>
<td>68.6</td>
</tr>
<tr>
<td>$V$ (cm)</td>
<td>50</td>
<td>50.8</td>
</tr>
<tr>
<td>$D$ (cm)</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>$F$ (lifts/min)</td>
<td>2, 6, 10</td>
<td>6.2</td>
</tr>
<tr>
<td>$F_{\text{max}}$ (lifts/min)</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>4.08</td>
<td>5</td>
</tr>
</tbody>
</table>
INDUSTRIAL LIFTING AND FATIGUE

According to their classification, when frequency of lift for this task equalled 2 or 6 lifts/min the job was "moderate work," while 10 lifts/min constituted "heavy work."

Finally, it is widely accepted (Astrand and Rodahl, 1977; Petrofsky and Lind, 1978) that when the heart rate does not stabilize after approximately 5 min of work, this is an indication the task is excessively fatiguing and that more than 50% of \( \dot{V}O_2 \) max is being expended. For all twelve subjects the heart rate stabilized when working at 2 lifts/min. Four subjects' heart rate (33%) did not stabilize within 5 min at 6 lifts/min. At 10 lifts/min 9 subjects' heart rate (75%) did not stabilize.

At no lifting frequency did the muscle strength (MVC) decrease significantly compared to baseline measures. The population means obtained for the present experiment were 29.9, 63.9, and 50.9 kg respectively for the 3 strength tests (Table 4). These values are all within one standard deviation of the previously reported strengths (Garg and Ayoub, 1980; NIOSH, 1981). Thus, the strength values were consistent with those of a normal, healthy male working population.

Garg (1983) also found that muscle fatigue may not appear even though other evidence of fatigue exists. Perhaps, with a lifting session of only 30 min, one observes more of a "warming up" phenomenon of the muscles rather than their fatigue, at least at the work loads employed in the present study.

Borg's RPE scale was so constructed that the heart rate of a normal, healthy middle-aged man can be predicted if the RPE value is multiplied by 10 (Borg, 1971). This relationship, HR/RPE=10, is held to be correct for medium intensities of physical stress (Borg, 1971).

Aristila et al. (1974) and Habes et al. (1983) obtained linear and repeatable perceived exertion levels. The data of Asfour et al. (1983) showed "interrater agreement" with standard deviation values ranging from 0.99-2.96. They found that the 10:1 ratio HR: RPE was reduced for high work loads.

The present experiment corroborated the above observations. Tables 3 and 5 show peak heart rate values, RPE values, and their ratios for all three lifting frequencies. Standard deviations for RPE values ranged from 1.6-1.90, showing good interrater agreement. The ratio of HR: RPE was approximately 10 for the middle lifting frequency. This ratio was reduced for the more stressing high frequency lift, as was found by Asfour, et al. (1983).

Garg's (1983) study indicated that work which produces an RPE value of more than 11 (equivalent to a heart rate of 110 beats/min for whole body exertion) is probably fatigue-generating. Accepting that, lifting at 2 lifts/min was not fatiguing, six lifts/min was marginally acceptable and lifting at 10 lifts/min clearly produced fatigue.

RPE values were consistent with the additional subjective fatigue responses elicited. All subjects felt that lifting at the low frequency was not unduly taxing. Lifting at the moderate frequency was acceptable to most subjects-only two ex-
experienced pain. However, lifting ten times per minute was painful to 83% of the subjects, and only 42% felt they could continue at that pace for a full hour. The subjects were not asked if the pace was sustainable for a full 8-hr shift.

CONCLUSIONS

The lifting frequencies for the laboratory simulation were chosen so that they task would be: (1) less than NIOSH’s (1981) AL (2) equal to the AL and (3) equal to MPL for the 3 frequencies, respectively.

According to NIOSH, jobs as stressing as the AL are expected to be suitable to 99% of all male and 75% of all female workers. Lifting 2 times per minute, under the given conditions, was expected to be well within the AL, thus lightly stressing. All the evidence obtained from heart rate, strength tests, and perceived fatigue confirms this expectation.

Lifting 6 times per minute was expected to be equal to the AL. As such, it is not surprising that the data do not clearly indicate the lift’s safety, though they would lead one to lean in that direction. Work pulse and peak pulse were both barely within the accepted limits. No muscle fatigue was observed, and the mean RPE value was slightly less than a previous investigator’s recommended limit. Garg’s (1983) additional subjective fatigue data showed most subjects able to perform at that lifting frequency without pain.

The NIOSH (1981) Guideline indicates that lifts equal to the MPL are suitable to only 25% of all male and 1% of all female workers. Lifting 10 times per minute in our study was expected to be equal to the MPL. The data confirmed this. Work heart rate and peak heart rate values indicated excessive fatigue. Though the strength tests did not indicate fatigue, the measures of perceived fatigue contradicted this. The mean RPE value was 15.2, assessing the exertion as “hard.” Most subjects experienced pain, and few indicated they could lift at that frequency a full hour.

At least for this particular simulation of an industrial lifting task, the NIOSH Guideline seems to accurately predict the level of fatigue produced at three distinct lifting frequencies.

Traditionally, industrial work standards have been based on time and motion studies without any regard to the physiological and psychological needs of workers (Garg, 1983). In addition, piecework incentives are extremely common for assembly or lifting jobs. These incentives encourage workers to place extreme stress on their bodies. Whether this practice results in increased risk of injury from chronic trauma, decreased vigilance, or the bypassing of safe work practices is a question that warrants investigation.

Regardless, job design and work standards which are more consonant with the capabilities and needs of the individual worker are necessary. Injury statistics and the workers themselves attest to that fact.
Special thanks are due to Dr. D. Badger of the National Institute for Occupational Safety & Health, Cincinnati, Ohio. Besides supplying some of the required laboratory equipment, his expertise and counsel were crucial to this project.

REFERENCES


