Memorandum

Date: May 3, 2001

From: Roy M. Fleming, Sc.D., Director, Research Grants Program RMF
Office of Extramural Programs, NIOSH, D30

Subject: Final Report Submitted for Entry into NTIS for Grant 5 R18 OH003202-03.

To: William D. Bennett
Data Systems Team, Information Resources Branch, EID, NIOSH, P03/C18

The attached final report has been received from the principal investigator on the subject NIOSH grant. If this document is forwarded to the National Technical Information Service, please let us know when a document number is known so that we can inform anyone who inquires about this final report.

Any publications that are included with this report are highlighted on the list below.

Attachment
cc: Sherri Diana, EID, P03/C13

List of Publications

Dempsey PG, Sorock GS, Cotnam JP, Ayoub MM, Westfall PH, Maynard W, Fathallah F, O'Brien N: Field Evaluation of the Revised NIOSH Equation. In: Proceedings of the XIVth Triennal Congress of the International Ergonomics Association and 44th Annual Meeting of the Human Factors and Ergonomics Society, Santa Monica, CA: Human Factors and Ergonomics Society, 5:724-727, 2000b

Dempsey PG, Fathallah FA: Application Issues and Theoretical Concerns Regarding the 1991 NIOSH Equation Asymmetry Multiplier. International Journal of Industrial Ergonomics 23:181-191, 1999

Title: Field Evaluation of NIOSH Lifting Equations
Investigator: Mohamed M. Ayoub, Ph.D.
Affiliation: Texas Tech University
City & State: Lubbock, TX
Telephone: (806) 742-3543
Award Number: 5 R18 OH003202-03
Start & End Date: 3/1/1996–8/31/2000
Total Project Cost: $576,316
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Abstract:
This study was proposed to evaluate the NIOSH equations of 1981 and 1991 to determine their ability to predict back injury. The proposed study called for 2000 cases; however, only data for 444 cases was collected for which LIs (lifting index) were calculated. Only 406 out of the 444 cases had positive exposure hours. In the descriptive analysis, all 444 were included. For relating outcomes to predictors, only 406 subjects with positive exposure hours were included.

Prior to carrying out the study as proposed, a pilot study was conducted to develop data collection methods, the associated questionnaires and other forms, and to identify the problems that may be encountered in the process. One of the major problems encountered is the discovery that the 1991 equation applied to a small percent of jobs identified. This resulted in the revision of the data collection protocol to include a higher percentage of manual handling jobs, particularly complex jobs such as those commonly found in storage and distribution sectors.

While the data are sparse, a statistically significant prospective relationship between LI (both 81 and 91) appears to be confirmed. Due to sparseness of the data, statistically significant modifiers of LI effects are not found. The only variable that comes close to significance is subject weight, which shows a decreasing effect on injury probability.

Due to the small number of injuries, the ability to make firm conclusions was hampered. In two formal analyses, the lifting index 1981 equation (L181) model appeared to be a better predictor, while in the simple logistic regression analysis, the lifting index for the 1991 equation (LI91) model appeared to be a better predictor.

It was also noted that mild evidence of non-liner increases in injury probability as a function of LI91 also noted by Waters et al (1999). Such nonlinear effects when using the LI81 index was not noticed in this study.

The primary findings include: (1) Many jobs were excluded because of the selection criteria and the requirements outlined in the users' manual. (2) The equation parameter ranges were often violated. In such cases, the Recommended Weight Limit (RWL) was zero which resulted in an LI of infinity. (3) Even though the sample of jobs was biased towards jobs amenable to analysis with the revised NIOSH equation, the majority of jobs

studies technically violate restrictions on the maximum shift length (8 hours) and that no other significant Manual Materials Handling (MMH) tasks be performed. (4) Difficulties in measuring some of the parameters, particularly angles of twist and task frequencies were noted. (5) Jobs containing multiple tasks created difficulty in calculating the combined Li's as proposed by the equation. This often resulted in large values for LI.

Publications

Dempsey PG, Sorock GS, Cotnam JP, Ayoub MM, Westfall PH, Maynard W, Fathallah F, O'Brien N: Field Evaluation of the Revised NIOSH Equation. In: Proceedings of the XIVth Triennal Congress of the International Ergonomics Association and 44th Annual Meeting of the Human Factors and Ergonomics Society, Santa Monica, CA: Human Factors and Ergonomics Society, 5:724-727, 2000b

Dempsey PG, Fathallah FA: Application Issues and Theoretical Concerns Regarding the 1991 NIOSH Equation Asymmetry Multiplier. International Journal of Industrial Ergonomics 23:181-191, 1999

FIELD EVALUATION OF NIOSH LIFTING EQUATIONS

FINAL REPORT

GRANT #5 R18 OHO3202

PREPARED BY:

TEXAS TECH UNIVERSITY
INDUSTRIAL ENGINEERING DEPARTMENT
AND
INFORMATION SYSTEMS &
QUANTITATIVE SCIENCES
LUBBOCK, TEXAS 79424

M.M. AYOUB

P. WESTFALL

LIBERTY MUTUAL INSURANCE COMPANY
RESEARCH CENTER FOR
SAFETY & HEALTH
HOPKINTON, MASSACHUSETTS

PATRICK G. DEMPSEY
GARY S. SOROCK
JOHN COTNAM
WAYNE MAYNARD
NIALL O'BRIEN
FADI A. FATHALLAH

NOVEMBER, 2000

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LIST OF ABBREVIATIONS

MMH - Manual Materials Handling

LBD - Lower Back Disorder

LI - Lifting Index

LI_{81} - Lifting Index for 1981 equation

LI_{91} - Lifting Index for 1991 equation

RWL - Recommended Weight Limit

AL - Action Limit

JSI - Job Severity Index

LBP - Lower Back Pain

LBPD - Low-Back Pain Disability

LSR - Lifting Strength Rating

JSR - Job Strength Rating

SHP - Safety and Health Professionals

OSHA - Occupational Safety and Health Association

NIOSH - National Institute of Occupational Safety and Health

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Abstract

This study was proposed to evaluate the NIOSH equations of 1981 and 1991 to determine their ability to predict back injury. The proposed study called for 2000 cases, however, only data for 444 cases were collected for which LIs (lifting index) were calculated. Only 406 out of the 444 cases had positive exposure hours. In the descriptive analyses, all 444 were included. For relating outcomes to predictors, only 406 subjects with positive exposure hours were included. All statistical analyses were performed using SAS/STAT® software version 8.0.

This epidemiological study had five specific aims. These were:

(1) To determine if lifting index (LI) for jobs is related to the incidence and severity of low back disorder (LBD),

(2) to prospectively determine if the relationship between the LI value and probability of LBD is different for workers of different personal characteristics,

(3) to determine the relationship between the equation multipliers and incidence of LBD,

(4) to determine if an alternate LBD prediction model can be developed, and

(5) to qualitatively evaluate the usability of the NIOSH equation in practical situations.

Prior to carrying out the study as proposed, a pilot study was conducted to develop data collection methods, the associated questionnaires and other forms, and to identify the problems that may be encountered in this process. One of the major problems encountered is the discovery that the 1991 equation applies to a small percent of jobs identified. This resulted in the revision of the data collection protocol to include a higher percentage of manual handling jobs, particularly complex jobs such as those commonly found in storage and distribution sectors.

The results of the study are summarized below.

While the data are sparse, a statistically significant prospective relationship between LI (both 81 and 91) appears to be confirmed. Due to sparseness of the data, statistically significant modifiers of LI effects are not found. The only variable that comes close to significance is subject weight, which shows a decreasing effect on injury probability.

Due to the small number of injuries, the ability to make firm conclusions was hampered. In two formal analyses, the lifting index for the 1981 equation (LI81) model appeared to be a better

predictor, while in the simple logistic regression analysis, the lifting index for the 1991 equation (LI91) model appeared to be a better predictor.

It was also noted that mild evidence of non-linear increases in injury probability as a function of LI91 also noted by Waters *et al* (1999). Such nonlinear effects when using the LI81 index was not noticed in this study.

These data collected and experiences of those involved in data collection were summarized to evaluate the usability of the revised NIOSH equation. The primary findings include:

* Many jobs were excluded because of the selection criteria and the requirements outlined in the users' manual.

* The equation parameter ranges were often violated. In such cases, the RWL was zero which resulted in an LI of infinity.

* Even though the sample of jobs was biased towards jobs amenable to analysis with the revised NIOSH equation, the majority of jobs studied technically violate restrictions on the maximum shift length (8 hours) and that no other significant MMH tasks be performed.

* Difficulties in measuring some of the parameters, particularly angles of twist and task frequencies were noted.

* Jobs containing multiple tasks created difficulty in calculating the combined LI's as proposed by the equation. This often resulted in large values for LI.

SIGNIFICANT FINDINGS

Based on this epidemiological study the following significant findings can be reported:

(1) While the data are sparse, a statistically significant prospective relationship between LI for both the 1981 and the 1991 NIOSH equations appear to be confirmed.

(2) Due to sparseness of the data, statistically significant modifiers of LI effects were not found. One variable, the weight of the subject, comes close to significance. This weight shows an estimated decreasing effect on injury probability, although it is not statistically significant.

(3) It was noted in two formal analyses that the LI for the 1981 equation model appear to be a better predictor, while in the simple logistic regression analysis, the LI for the 1991 equation model appeared to be a better predictor.

(4) The results of this study seem to support the results reported by Waters, et al (1999) who noted a decrease in injury probability for LI > 3 for the 1991 equation. Such decreases were not noted when using the 1981 equation.

(5) In the data collected for this study, about one third of manual materials handling tasks have one or more parameter values exceed the acceptable ranges. In such cases, the associated multiplier becomes 0, the RWL is 0, and the LI becomes infinite. In reality, the task does not pose infinite risk simply because the parameter exceeds the limit. Extrapolation formulas were used so that those data points could be used in the analysis.

(6) Users of the NIOSH equation (even if they have MMH expertise) should receive formal training on how to measure the equation parameters and apply them.

(7) It is important to design and test any training program to train the equation users.

USEFULNESS OF FINDINGS

Several findings were realized from this study that can be of some use to the user of both the NIOSH equations of 1981 and 1991. There are listed below:

(1) If one were to carefully assess all the restrictions inherent in the NIOSH equations, few manual materials handling exposures (at least in the United States) are amenable to analysis with these equations. Therefore, the application of the equations will most likely result in violations to be made. The extent of the violations allowed will actually depend upon the expertise and training of the analyst.

(2) The NIOSH equations of 1981 and 1991 have shown a definite relationship between the LI's and probability of injury. Obviously this is of value for practitioners who use the equation for evaluation of risks.

(3) The case of very large numbers of tasks being performed, such as warehouse order pickers, represents a job that does not fit the task description required. The task may be considered assembling the orders, and it is impossible to precisely specify the parameters of individual lifting and lowering tasks within this broader task since the contents of orders are virtually stochastic. A different analysis approach than that considered by the NIOSH equation (1991) may be developed to handle such exposures. Techniques incorporating sampling schemes, such as OWAS (Karhu et al., 1977) or PATH (Buchholz et al., 1996), are capable of analyzing the broader order assembly 'task' are possibilities. For both techniques, work sampling is used to estimate the characteristics of the job demands to alleviate the need to continuously record data. Ideally, a task description should be developed first and an analysis technique suitable for the exposure should then be selected. Although individual manual handling actions like lift, lower, push, pull, and carry, have traditionally been assumed to be the 'task,' many jobs are far too complex to comprehensively quantify using these terms.

(4) This study provided an insight into the training of individuals who may use the NIOSH 1991 equation. Based on our experience, it is recommended that emphasis should be placed on having potential users trained with actual measurements (hands on) rather than a lecture type training.

(5) When training, our experience indicates that measurement of horizontal location of the load and frequency of handling should receive priority in such training. Errors in these two parameters can render the analysis meaningless in some tasks.

(6) A critical issue which was discovered but not addressed in this study was the issue of strategies adopted in job analysis and its impact on equation parameter measurements. A challenging aspect found during this study was determining just what the individual tasks were0 and what the equation parameters should be. Some jobs were sufficiently complex that defining distinct tasks was difficult. Hence, the NIOSH equation may only be useful to individuals with sufficient understanding of the limitations and assumptions of the methods being used.

Appendix D

Publications

PUBLICATIONS

Dempsey, P.G., and Fathallah, F.A. (1999). Application issues and theoretical concerns regarding the 1991 NIOSH equation asymmetry multiplier, **International Journal of Industrial Ergonomics**, 23, 181-191.

Dempsey, P.G., Sorock., G.S., Cotnam, J.P., Ayoub, M.M., Westfall, P.H., Maynard, W., Fathallah, F., and O'Brien, N. (2000b). Field Evaluation of the Revised NIOSH Equation. In: **Proceedings of the XIVth Triennial Congress of the International Ergonomics Association and 44th Annual Meeting of the Human Factors and Ergonomics Society** (5•724-5•727). Santa Monica, CA: Human Factors and Ergonomics Society.

1.0 INTRODUCTION

In 1981, the National Institute for Occupational Safety and Health (NIOSH) published the *Work Practices Guide for Manual Lifting* (NIOSH, 1981) and in 1991 a revised version of the equation was presented at a national conference (Putz-Anderson and Waters, 1991). The NIOSH equations attempt to simultaneously satisfy biomechanical, physiological and psychophysical criteria. Additionally, epidemiological results were considered during development of the equations.

Longitudinal studies that include workers from different industries performing a variety of manual lifting jobs for different durations are needed to evaluate the efficacy of the revised lifting equation in reducing back injuries due to manual handling (Pizatella *et al.*, 1992; Putz-Anderson and Waters, 1991). This research project is a prospective study aimed at addressing this issue. The volume of data collected will also allow for qualitative assessments of the usability of the new lifting equation in practical situations, also an area of interest to NIOSH (Pizatella *et al.*, 1992).

Putz-Anderson and Waters (1991) and Waters *et al.* (1993) define the ratio of the actual load lifted by a worker to the recommended weight limit (RWL) as the lifting index (LI). However, the relationship between LI and injury is not known (Waters *et al.*, 1993). A primary goal of this research project is to empirically estimate this relationship so that the LI can be effectively utilized to gauge the percentage of the workforce that a given task will place at risk for low-back injury.

Putz-Anderson and Waters (1991) suggest that all jobs exceeding the RWL would be redesigned before such an evaluation. This research investigation will examine a range of jobs, including both jobs in which the RWL is less than the actual weight lifted and those in which the actual weight lifted is greater than the RWL. The rational for this is so that the relationship between the LI and low-back disorders can be determined over a broad spectrum of tasks, and hence a wide range of LI values, present in industry.

Another approach to setting manual handling guidelines is the psychophysical approach. This approach is based upon the premise of allowing subjects to select "maximum acceptable" workloads that will prevent fatigue, discomfort, and subsequent injury. The largest and most comprehensive psychophysical database is that of Snook and Ciriello (1991). This database forms the basis of CompuTask™, a software program for evaluating manual materials handling (MMH) tasks. The program calculates the percentage of the worker population that a task is acceptable to based upon the workplace and task parameters inputted. This approach to MMH guidelines is considerably broader than the NIOSH lifting equations in that CompuTask™ also evaluates pushing, pulling, and carrying tasks.

While there is some epidemiological support for the psychophysical approach, there have been no large prospective epidemiological investigations of psychophysical guidelines. Like the NIOSH equations, there is a need for longitudinal studies to investigate the ability of psychophysical guidelines to reduce the incidence and severity of MMH-related injuries,

1.1 Specific Aims

The specific aims of this research project were:

1.) To prospectively determine if the LI for jobs from various industries is related to the incidence and severity of low-back disorders. The ratio of actual weight lifted to the 1981 action limit (AL) (NIOSH, 1981) will be evaluated for comparison purposes. The lifting indices based on the 1981 and 1991 equations will be referred to as LI_{81} and LI_{91}, respectively, when distinction is necessary.

2.) To prospectively determine if the relationship between the LI value and probability of low-back injury is different for workers of different sex, age, height, weight, and history of prior low-back pain or injury episodes. Other job-related factors, such as percent cycle time that includes lifting or lowering, not included in the NIOSH equations, will also be examined.

3.) To compare the current functional forms of the four multipliers that are continuous (i.e. VM, HM, DM, AM as defined by Waters *et al.* (1993)) to empirically determined relationships between V, H, D, and A and the incidence of back injuries. The relationship between frequency and injury will also be compared to the frequency multipliers; however, the frequency multipliers were designed based on physiological concerns (Waters *et al.*, 1993). The analysis will include provisions for assessing the relationship between the three levels of couplings (good, fair, and poor) and injury. The analysis will also allow for comparisons between the 1981 multipliers and the empirically determined functions, some of which are very similar in form to their 1991 counterparts.

4.) To determine if an alternate injury prediction model developed from the data collected that incorporates the 6 variables currently represented in the RWL equation, personal variables, job-related factors, and their interaction terms would be more appropriate than the NIOSH equation or useful as a supplement.

5.) To qualitatively evaluate the usability of the new equation in practical situations. Problems encountered during data collection and during computation may suggest alternative data collection procedures and analysis methods.

1.2 BACKGROUND AND SIGNIFICANCE

The concept of relating the task demands: lifting capacity ratio to the incidence and severity of MMH injuries has been investigated in previous research. In terms of the LI_{81} and LI_{91}, AL and RWL can be viewed as measures of lifting capacity and the actual weight lifted represents task demands.

Ayoub *et al.* (1983) investigated the ability of the Job Severity Index (JSI), a time and lifting-frequency weighted ratio of job demands to worker capacity, to predict the incidence and severity of MMH-related injuries. Worker lifting capacities were based on Ayoub *et al.*'s (1978) predictive equations. Liles *et al.* (1984) reported the results of a field study utilizing a total of 453 subjects, 209 from the Ayoub *et al.* (1983) study. Incidence and severity rates (number of injuries and lost days per 200,000 exposure hours, respectively) rose rapidly at JSI values greater than 1.5.

Chaffin and Park (1973) related the ratio of maximum load lifted to the maximum isometric strength of a 97.5 percentile male, lifting in the same position, to incidence of low-back disorders. This ratio was called the Lifting Strength Rating (LSR) and the low-back incidence rates began to increase significantly at LSR values greater than 0.2.

Chaffin *et al.* (1978) used the Job Strength Rating (JSR), the ratio of the average task specific isometric strengths of all workers in a job to the maximum strength requirement of the job. The relationship between JSR and incidence rate of low back disorders appeared to be fairly linear. The relationship between JSR and severity rate was not linear, but values greater than 1 resulted in considerably higher severity rates than values less than 1.

LI and the 3 methods discussed above (JSI, LSR, and JSR) are all based on the theoretical construct that injury potential increases when job demands exceed operator capacity. The methods differ in the manner that operator capacity is defined. LI and LSR use population capacities as the definition, whereas JSI and JSR use individual measurements to define operator capacity. With the exception of LI, field studies have indicated that this approach is valid.

Marras *et al.* (1993) performed a retrospective study, and they reported that they developed a logistic regression model with lift rate, box weight, moment arm, lift origin, and distance traveled, the variables in the 1981 equation. Unfortunately, they did not report the model (significance, parameter estimates, etc.).

The shape of the risk function for the LI is not known, hence it is not possible to quantify the precise degree of risk associated with increments in the LI, nor is there certainty about whether an LI of 1 is a reliable boundary differentiating an increase in risk and no increase in risk for some fraction of the population (Waters *et al.*, 1993). RWL provides a lifting capacity estimate, and this estimate is equal for all members of the workforce. The AL and RWL were designed to accommodate about 99% of the male workforce and 75% of the female workforce, so a given LI value may not represent equal risk for males and females. Epidemiological evidence is needed to quantify potential differences between the sexes. Furthermore, other personal variables discussed below may affect the relationship between LI and injury probability, and should also be investigated.

Aside from the JSI study (Liles *et al.*, 1984), the other epidemiological investigation of the psychophysical approach was performed by Snook (1978). Snook found that 25% of jobs investigated involved tasks acceptable to less than 75% of the population, but that these jobs resulted in one half of the back injuries recorded. Thus, this study was retrospective in nature, with only qualitative analyses of the relationship between the percentage of the population accommodated and injury incidence.

When conducting epidemiologically-based studies, risk factors that affect rates of the disease or injury must be included in the study, or controlled, to prevent confounding factors from unduly influencing the results and subsequent interpretations. Researchers have found that a prior history of a low-back disorder (Battié *et al.*, 1990; Biering-Sørensen, 1983c; Nordgren *et al.*, 1980; Rowe, 1969; Troup *et al.*, 1987; Venning *et al.*, 1987), length of time since the last low-back episode (Biering-Sørensen, 1983a; Biering-Sørensen, 1984), the length of work absence (Troup, 1981), history of treatment for pain or chiropractic visits (Bigos *et al.*, 1992), previous sciatica (Biering-Sørensen, 1983b), frequency of previous low-back episodes (Biering-Sørensen, 1983a; Burton and Tillotson, 1991) and the number of previous low-back episodes (Chaffin and Park, 1973; Troup, 1981) were related to future reports of low-back pain. Hull (1982) found that past history was the most commonly used prognostic element among a group of 215 physicians surveyed in the United Kingdom, Holland and Israel.

Some researchers have found that LBP may take an intermittent, but chronic course, once an episode has occurred. Rowe (1969) found that 85% of an experimental sample reported recurrent episodes of low-back pain (LBP) during their working careers. Recurrence rates in the first year alone, after the initial episode, have been found to be as high as 48.5% (Troup *et al.*, 1981) and 62% (Bergquist-Ullman and Larsson, 1977). The ability of the NIOSH equation and CompuTask™ to protect workers from injury may differ for those with and without a history of low-back injury, and if there are differences in injury probabilities due to history of prior injury, they need to be considered.

Anthropometric variables such as height, weight, and muscle strength are potential modifiers of low-back disorder risk (e.g. Ayoub and Mital, 1989; Biering-Sørenson, 1984; Frymoyer, 1989; Griffith; 1992; Mital *et al.*, 1993). Epidemiological research has shown age to be associated with an increased risk of low-back disorders (e.g. Battié *et al.*, 1990; Kelsey 1975a,b). The literature contains conflicting information concerning age; however, the stress supporting capacity of the spine declines with age and age should be treated as a potential risk factor (Ayoub and Mital, 1989). Additionally, the relationship between anthropometry and predicted lifting capacity has been empirically demonstrated (e.g. Ayoub *et al.*, 1978). The personal variables mentioned may influence the LI risk function, and if so, the empirically determined relationships can be used to assist the design and evaluation of MMH tasks assessed with the NIOSH equation.

The 1991 NIOSH equation is valid for both lifting and lowering tasks. Although lifting and lowering have been compared with respect to biomechanical criteria such as peak lumbo-sacral stresses, intra-abdominal pressure, and electromyography of the trunk and lower extremity musculature (e.g. DeLooze *et al.*, 1993; Gagnon and Smyth, 1991; Kumar and Davis, 1983) and physiological criteria such as oxygen uptake (e.g. Mital and Ayoub, 1981), the two types of MMH tasks have not been compared with respect to epidemiological criteria such as incidence and severity of low-back injuries. The proposed research will provide provisions for such an investigation, although the investigation will be dependent upon the jobs selected. For example, if few jobs contain a large portion of lowering tasks, it will be difficult to assess differences in risk between lifting and lowering. Such an assessment would require a reasonable representation of jobs ranging from 100% lifting to 100% lowering in order to reliably estimate differences with statistical methods.

The NIOSH equation is valid for lifting and lowering tasks, and does not include provisions for assessing other MMH tasks such as pushing, pulling, holding, and carrying. Waters *et al.* (1993) suggest that metabolic analyses may be necessary when such tasks are common, but these tasks often represent biomechanical as well as physiological demands. For this reason, all such non-lifting and -lowering MMH tasks will be recorded to characterize the tasks. However, such an analysis is not a primary goal of the proposed research and an attempt to include provisions may confuse the goals outlined in earlier. As with investigating the risk differences between lifting and lowering, investigating non-lifting and -lowering tasks would require selecting jobs that contain a broad spectrum of other such tasks as a percentage of job duties. Unfortunately, such a criterion for job selection is rather impractical for an observational study design.

In contrast, CompuTask™ provides provisions for analyzing pushing, pulling, and carrying tasks in addition to lifting and lowering tasks. For the CompuTask™ evaluation, all MMH tasks will be considered.

2.0 PILOT STUDY

A pilot study was conducted to investigate the data collection process in the field. The primary reasons for conducting the pilot study were: (a) to examine the effectiveness of the data collection instructions, (b) to determine if there were any problems with the questionnaire used to solicit information from subjects, (c) to obtain an estimate of how long data collection would take on a per-subject basis, and (d) to obtain an understanding of how willing various organizations would be with respect to participating in the project.

2.1 METHODS

The pilot study was conducted using four safety and health professionals (SHPs) from the northern United States. The SHPs were provided with training concerning the data collection protocol. The training lasted approximately two hours. Since the complete final protocol and data collection methodology are presented in the next section, the methods will not be discussed here.

2.2 RESULTS

The results of the pilot study are primarily the problems encountered during data collection. The questions from the SHPs during the data collection phase indicated that more training needed to be provided. This was accomplished by providing an expanded training program for the main data collection, which is discussed in more detail later.

2.2.1 Problems Encountered

(1) The asymmetry measurements needed to be clarified to clearly reflect that the measurements at the origin and destination are relative to the "neutral" position. An SHP misinterpreted the asymmetry measurement as being the total displacement of asymmetry, versus two discrete postures.

A second problem with asymmetry is that SHPs recorded most asymmetry angles as multiples of 5°, with many values of 45° and 60°. This indicates that the asymmetry measurements tended to be rough estimations. To solve this problem, a protractor with two rulers for alignment with the asymmetry line and sagittal line was developed. Training was developed to include specific instructions concerning how to measure asymmetry with the device.

(2) There needed to be a minimum carry distance in order for the task to be considered a carry. To solve this problem, instructions were developed that a carry is not recorded unless the individual takes more than 2 steps.

(3) The frequency factor was found to be confusing. For example, a case was presented where an individual packs boxes. The boxes are palletized into a 3*3 configuration over a period of 45 minutes. The question was how to assign a frequency to each level of the pallet given that Waters *et al.* (1994) indicate that the frequency determination should be made over a 15-minute sampling period. Since this method would induce errors, the training was redesigned to provide example of how to calculate frequency for such situations. For machine paced tasks, spending 15 minutes to calculate frequency is wasteful. For less frequent tasks, 15 minutes is not sufficient. Thus, the time over which frequency is calculated is dependent upon the situation.

(4) A question was asked concerning what should be done when workers "toss" a load. While there are no MMH guidelines to assess activities such as this, SHPs were instructed to make a note on the data collection sheets that the load was being "tossed" or thrown.

(5) It was suggested that a task list be developed that will serve as checklist so that the SHPs can be certain that all needed information has been gathered. A checklist was developed using the pilot study SHPs' inputs, and is included in the data collection instructions.

3.0 MEASUREMENT VALIDITY STUDY

A common approach to the assessment of manual materials handling (MMH) tasks in industry is using criteria to judge the "acceptability" of the tasks. Task parameters measured at the workplace are used to calculate stresses associated with the task in the units of the criterion (e.g., Newtons of spinal compression). The observed value for the task is compared to a pre-defined criterion value to provide an assessment of stress. Thus, both of these values are important when performing workplace assessments.

There are two critical issues associated with this approach to MMH assessment at the workplace: (1) the appropriateness of the pre-selected criterion, and (2) the accuracy and precision of the observed value for the task(s) of interest. The pre-selected criterion needs to be capable of protecting the worker population from adverse outcomes, such as low-back disability, and therefore must represent a level of exposure that will be protective. This issue has received considerable attention in the literature (e.g., Dempsey, 1998; Leamon, 1994), and will not be discussed here. The second issue has received little attention so far. However, measurement error in the observed value may have a profound influence on the decision as to whether or not a particular MMH task presents a health risk in the workplace.

3.1. WORKPLACE ASSESSMENTS

Sufficient accuracy and precision of observed MMH criterion values are critical so that proper conclusions are drawn from the assessment. Poor accuracy and precision can lead to reduced sensitivity and specificity when using a pre-selected criterion, which may ultimately lead to an inappropriate allocation of the resources appropriated for ergonomic improvements. A cost/benefit analysis is only as good as the information available to perform the analysis.

The accuracy and precision requirements of specific parameter measurements are dependent upon the particular method, and different parameters within a given analysis method may require differential accuracy and precision. For example, equal errors in joint angles at the shoulder and knee for a biomechanical analysis will differentially affect spinal compression estimates. As will be illustrated later, this issue is relevant to the NIOSH equation.

3.2. EPIDEMIOLOGICAL STUDIES

Given the lack of validation of many MMH criteria (Dempsey, 1998; Leamon, 1994), the opportunity for epidemiologic investigation is extensive. A critical step in the investigation process is the exposure assessment of MMH tasks at the workplace. The accuracy and precision of the observed values of the MMH criterion of interest can have a direct impact on the results of the study.

In epidemiologic research, measurement error is one source of study bias that influences the validity of the results. When exposure variables are measured with some degree of error, and the error is constant irrespective of the value of the outcome classification, the point estimate of the effect of the association between exposure and outcome is reduced to some degree.

Exposure measurements may have multiple types and sources of error. The effects of these errors are usually complex and not easily predicted, and correction for these errors is often difficult (Flegal *et al.* 1991). Standardization of workplace measurements can help assure reliable estimates of exposure in epidemiological studies (Burdorf 1992; Hagberg 1992). Standardization can be enhanced by developing and testing methodologies for exposure assessment, which was one focus of the current study.

Like other MMH criteria, there is not extensive literature on application issues associated with the NIOSH equation. The study by Garg (1989) was used in the revision of the 1981 equation, and showed that the horizontal locations for lifting tasks varied between subjects, and the measured values tended to be larger than the approximation of 15 cm. plus half of the box width. The mean measured horizontal distances for different conditions were also considerably larger than the minimum value of 15 cm. (6 in.) used for the 1981 equation.

Recently, Dempsey and Fathallah (1999) examined the asymmetry multiplier of the 1991 equation. Using three independent sources of data, they concluded that there is substantial variation in how different individuals measure asymmetry when applying the equation in industry. Potential methods of increasing consistency of application include revising the multiplier and developing clearer instructional materials.

A study of the accuracy of 27 non-ergonomists' assessments of vertical location, horizontal location, asymmetry, coupling, and significant control was reported by Waters *et al.* (1998). The subjects measured parameters of an asymmetric lifting task in a laboratory eight weeks after a seven-hour training session. Significant differences between measured and actual asymmetry values were found, and 41% of the participants rated coupling incorrectly. The authors concluded that a one-day training class is sufficient to instruct users to properly measure the studied parameters. However, Burdorf and van der Beek (1999) recommend cautious interpretation since random sources of measurement error present in the workplace, as well as difficulties measuring frequency, may result in less favorable results for actual workplace use than those reported in a laboratory setting.

The objective of this study was to investigate the accuracy of parameter measurements required to apply the NIOSH equation. This information was used to assess the adequacy of the content of a four-hour training program developed by the authors.

3.3 METHODS

3.3.1 Subjects

Eight subjects (seven males and one female) participated in the study. All subjects held at least a BS degree in Engineering/Safety or other related fields and had limited experience in assessing MMH tasks in the field.

3.3.2 Apparatus

All lifting tasks involved handling 5 kg. cardboard boxes (26 cm high, 40.6 cm wide and 37.7 cm deep) with 7.6 cm wide by 2.5 cm high cut-out handles. The subjects were provided with a spring scale to measure box weight, a tape measure to measure horizontal and vertical locations, and a protractor with reference guides to measure the asymmetry angles.

3.3.3 Procedures

Prior to data collection, the subjects underwent a four-hour training session. The 3.5 hour lecture included definitions of variables and methods of measuring the workplace and task parameters necessary to calculate the NIOSH lifting index. Approximately 45 minutes of the lecture were devoted to issues specific to an ongoing epidemiologic study being conducted. The content of the training material and all variable definitions were based on the "Applications Manual for the Revised NIOSH Lifting Equation" (Waters *et al.*, 1994). Actual RWL and LI calculations were not covered since the authors strongly recommend using computer software to perform the calculations. Throughout the training session, subjects asked pertinent questions about specific measurements. Measurement demonstrations were made by the authors during a 0.5 hour interactive session for parameters measured with the protractor and tape measure (e.g., asymmetry, horizontal distance). After the training session, each subject consented to participate in the study and was asked to gather data on the simulated tasks.

A trained volunteer performed five simulated lifting/lowering tasks: 1) a symmetric lift, 2) an asymmetric lift, and 3) a palletizing operation consisting of three asymmetric lowering tasks. The tasks were chosen to represent asymmetric and symmetric tasks, and single and multiple-task situations. Reference measurements were made by two of authors with expertise in the NIOSH equation. The reference values for parameters of all tasks are given in Table 1.

Table 1. Reference parameter values for the five lifting/lowering tasks.

Task	V_O	V_D	H_O	H_D	A_O	A_D	F	Duration
1 - Symmetric	25.4	99.1	48.3	83.8	0°	0°	6	Short
2 - Asymmetric	22.9	99.1	45.7	68.6	0°	48°	4	Long
3 - 1st Palletizing	149.9	25.4	[a] 66.0	[a] 58.4	[a] 50°	[a] 61°	4	Long
4 - 2nd Palletizing	124.5	50.8	[a] 66.0	[a] 58.4	[a] 50°	[a] 61°	4	Long
5 - 3rd Palletizing	99.1	76.2	[a] 66.0	[a] 58.4	[a] 50°	[a] 61°	4	Long

[a] Average values, see text for explanation

V_O = Vertical height at the origin; V_D = Vertical height at the destination; H_O = Horizontal distance at the origin; H_D = Horizontal distance at the destination; A_O = asymmetry at the origin; A_D = asymmetry at the destination; F = frequency (lifts or lowers per minute). All distance measures are in centimeters.

The first task (see Figure 1a) was a single lift assumed to be continuously performed for a period of 45 minutes before performing a one-hour paper-work task, simulating a short-duration task. The task duration and rest break information were provided to subjects on paper in order to calculate the duration.

The second task (see Figure 1b) was an asymmetric lifting task assumed to be continuously performed for a period of two hours before taking a thirty-minute lunch break, simulating a long-duration task.

Tasks 3-5 (see Figure 1c) simulated a palletizing operation. The volunteer lowered six boxes (three layers of two boxes) from a table at his right side and stacked them (three levels) at floor level (see Figure 1c). It was assumed that each of the layers constituted a single task. For a given layer (task), the two boxes comprising that layer had different horizontal distances and asymmetries. For these variables, the average parameter values of the two boxes were used for the reference measurements. For each task, the frequency was 4 lowers per minute. The operation was assumed to be continuously performed during a four-hour period, simulating a long-duration task.

Figure 1. Illustration of destination for symmetric task (A), asymmetric task (B) and palletizing operation (C).

A.

B.

C.

All the lifting/lowering tasks were performed with significant control and the box was rated as having "fair" coupling characteristics. The volunteer was instructed not to move his feet while performing the tasks. Also, the volunteer did not pause while the subjects made the measurements. This was meant to simulate situations in industry where the workers do not stop or pause while measurements are made. Prior to the experiment, the volunteer was trained, and performed each task for several hours to assure consistency and repeatability of the task's reference measurements.

Each subject started the data collection by using a spring scale to weigh one of the boxes. The subject then started recording vertical location, horizontal location and asymmetry at the origin and destination, coupling, frequency, weight and significant control while the volunteer continuously performed the symmetric task, asymmetric task, and palletizing operation, consecutively. The volunteer stopped performing a given task and moved to the following one whenever the subject was through recording all the parameters. The subjects were provided with data sheets to record all information. Durations for all tasks were calculated after the measurements were completed.

3.3.4. Data Analysis

The mean and standard deviation were calculated for weight (W), vertical distance at the origin (V_O) and destination (V_D), horizontal distance at the origin (H_O) and destination (H_D), asymmetry at the origin (A_O) and destination (A_D), frequency (F), and LI at the origin (LI_O) and destination (LI_D). The RWL and LI values for each task were calculated at the origin and the destination of the lift as described by Waters *et al.* (1994) with two exceptions. The value of H_D for Task 2 (68.6) and the values of H_O (66.0) for Tasks 3-5 exceed the maximum value of 63 cm. In these cases, the RWL is technically equal to 0 (and the LI = ∞) since the horizontal multiplier is 0 when the bounds are exceeded. However, the authors chose to ignore this violation for the calculations since infinity values exclude meaningful statistical analysis. The multiplier itself accepts values greater than 63; thus, the value of the multiplier with the actual values were used. This is not unlike situations in industry where practitioners use a similar method or use a value of 63.

To test for significant differences between the subjects' measurements and the reference value (accuracy), a t-test statistic was computed for each variable.

The sensitivity of the Task 4 LI (destination was used) to changes in parameter values was evaluated by calculating the effect on the LI of using the minimum and maximum values of the individual multipliers. The minimum and maximum multiplier values represent the extremes of errors of under- or over-measurement, respectively. The six parameters studied included vertical location, travel distance, asymmetry angle, horizontal location, frequency, and load weight. The sensitivity is expressed by the range in LIs and the ratio of the highest to the lowest LI. This analysis provides insight into the range of potential errors that can be caused by individual parameter measurement errors for a fairly typical task.

Second, an analysis was made of the effect of measurement error on the calculated LI. Measurement variability for the six parameters was expressed by the standard deviation, and, subsequently, the 95% confidence interval around the LI was calculated. The references values were used for each parameter. Each standard deviation was then halved, and the procedure was repeated. It was assumed that the standard deviation represents random measurement error in the parameters. The standard deviation values for the displacement measurements were all set to 5 cm. to enhance comparison across parameters, and values for the other parameters were set by examining the experimental results. These values are somewhat arbitrary, and can be easily changed to examine errors of varying magnitudes. However, the values chosen were assumed to represent reasonable values.

3.4 RESULTS

The reference values, descriptive statistics of measurements made by the subjects (observed values), and results of t-tests for each parameter of all tasks are given in Table 2. Significant differences are from testing the hypothesis that the mean observed value is equal to the reference value. There was an overall tendency to underestimate the reference values.

For task 1, there was a significant difference between reference values and mean measured values for the vertical and horizontal locations at the origin. In spite of these differences, the mean LI value from the observed values was not significantly different from the reference LI value. Overall, the subjects had a tendency to underestimate the measures. Duration was calculated correctly as short by all eight subjects, significant control was correctly rated yes by five subjects, and coupling was rated correctly as fair by six subjects (two incorrectly rated coupling as good).

For task 2, there was a significant difference between the reference value and the mean measured value only for vertical location at the destination. This task had similar variation in LI values to task 1. Duration was calculated correctly as long by three subjects (five subjects rated duration as medium), significant control was correctly rated as yes by four subjects, and coupling was rated correctly as fair by seven subjects (one incorrectly rated coupling as good).

For tasks 3-5, there was a significant difference between reference values and mean measured values for the vertical and horizontal locations at the origin. Additionally, there was a significant difference between reference values and mean measured values for the vertical location at the destination and horizontal location at the origin. For task 4, the mean LI value for the origin was significantly different from the reference LI value. Duration was calculated correctly as long by all eight subjects, significant control was correctly rated yes by four subjects for task 3 and by five subjects for tasks 4 and 5, and coupling was rated correctly as fair by seven subjects for all three tasks (one incorrectly rated coupling as good).

Table 3 provides the sensitivity of the LI for task 4 to errors in parameter measurements. The ratio of the maximum LI to the minimum LI expresses the variability in potential LI values that can be

Table 2. Comparison between the reference and observed values for the five tasks 1 (symmetric lift).

Task		W	V_O	V_D	H_O	H_D	A_O	A_D	F	LI_O	LI_D
1	Reference:	5.0	25.4	99.1	48.3	83.8	-	-	6.0	0.8	1.2
	Observed Mean (SD):	4.9 (0.4)	21.0* (2.5)	85.2 (25.3)	40.3* (5.5)	80.3 (9.1)	-	-	6.5 (2.5)	0.6 (0.2)	1.0 (0.4)
2	Reference:	5.0	22.9	99.1	45.7	68.6	-	48	4.0	1.3	1.9
	Observed Mean (SD):	4.9 (0.4)	21.1 (2.5)	95.0* (2.6)	47.0 (7.8)	65.1 (17.6)	-	51.6 (7.2)	5.3 (2.8)	1.3 (0.2)	1.8 (0.5)
3	Reference:	5.0	149.9	25.4	66.0	58.4	50.0	61.0	4.0	2.3	2.0
	Observed Mean (SD):	4.9 (0.4)	125.4 (47.2)	20.6* (3.8)	48.4* (15.9)	53.5 (18.4)	39.4* (8.6)	37.0* (11.7)	5.3 (3.8)	1.4* (0.8)	1.5 (0.7)
4	Reference:	5.0	124.5	50.8	66.0	58.4	50.0	61.0	4.0	2.0	1.8
	Observed Mean (SD):	4.9 (0.4)	105.9 (33.9)	47.5 (8.6)	52.1 (21.8)	53.9 (19.1)	39.4* (8.6)	40.1* (7.6)	5.3 (3.8)	1.3* (0.7)	1.3 (0.7)
5	Reference:	5.0	99.1	76.2	66.0	58.4	50.0	61.0	4.0	1.6	1.4
	Observed Mean (SD):	4.9 (0.4)	90.0 (33.2)	65.4 (20.7)	50.6 (18.2)	53.2 (17.7)	39.4* (8.6)	40.1* (7.6)	5.3 (3.8)	0.9* (0.8)	1.0 (0.9)

LI_O = Lifting Index at the origin; LI_D = Lifting Index at the destination. *Significant at $p < 0.05$.

realized across the range of valid parameter values. Table 4 provides confidence intervals for the LI using the stated standard deviations for each parameter. The standard deviations were halved and the new confidence intervals were computed, yielding insight into the effect of more accurate parameter measurements. Tables 3 and 4 indicate that errors in the measurement of frequency and horizontal location have the largest effect on the LI.

Table 3. Sensitivity of the LI to the possible range of individual parameter values for Task 4 (destination).

	Possible range of multipliers			
Parameter	minimum-maximum	ratio	Multiplier in lifting task	Possible range in LI (min-max)
H_D	0.40-1.00	2.50	0.43	0.78-1.95
V_D	0.70-1.00	1.43	0.93	1.68-2.41
Travel distance	0.85-1.00	1.18	0.88	1.59-1.87
A_D	0.57-1.00	1.75	0.80	1.45-2.54
F	0.13-1.00	7.69	0.45	0.81-6.27
Coupling	0.90-1.00	1.11	0.95	1.72-1.91

Table 4. Effect of measurement error on the Lifting Index in the 1991 NIOSH lifting equation, given a lifting task with LI=1.81

Parameter	True measure	LI calculation with measurement error		LI calculation with reduced measurement error	
		SD	95% CI	SD	95% CI
Horizontal location (cm)	58.4	5.0	1.55-2.06	2.5	1.68-1.93
Vertical location (cm)	50.8	5.0	1.75-1.85	2.5	1.77-1.82
Vertical travel distance (cm)	73.7	5.0	1.78-1.81	2.5	1.79-1.81
Asymmetry angle (^{o})	61	7.3	1.72-1.89	3.7	1.76-1.84
Frequency	4	1.5	1.24-3.67	.7	1.47-2.31
Coupling	0.95	na	na	na	na
Weight (kg)	5	0.4	1.54-2.05	0.2	1.69-1.91

3.5 DISCUSSION

The measurement error results should be interpreted with respect to the sample size of eight, since the range of LI values (for example, 0.2 - 1.3 for the destination of Task 1) indicates practical significance, even if the differences are not statistically significant. On the other hand, the results indicate the presence of systematic errors. For example, the standard deviation for V_D for Task 1 is 25.3 cm. In this case, a participant misunderstood a measurement strategy presented. The instructor stressed the importance of making the origin and destination measurements at the points when the load first leaves the surface and when the load first touches down, respectively. When the load is lifted from or placed on a surface such that measurement of vertical location becomes difficult due to obstructions, the instructor indicated that the vertical location can be taken relative to the top of the surface and the height of the surface can be added to this value. However, a subject did not add the height of the surface when using this technique, causing the large variation. The training program was revised to avoid such confusion in the future.

The authors believe that the range of errors of other parameters can also be decreased through revising the content of training. The training program was revised to provide more focus on *techniques* for measuring parameters. Explicit techniques were provided for cases where the worker cannot stop to allow the analyst to make measures, as well as cases where the worker can stop. The latter case is ideal, but the authors have encountered numerous situations where minimal work stoppage is feasible. It should be noted that the experiment utilized the case where the worker does not stop, which enhanced measurement difficulty.

Several examples were also integrated into the training class that require participants to rate coupling and duration as well. For coupling, participants were asked to rate the handling of available objects, such as the overhead projector used for the training class. For duration, several textual examples were provided that included hypothetical durations of various activities that had to be rated as work time or rest time. Participants were asked to rate duration from this information, and the instructor then went through the calculations in detail. Finally, a session involving measurement of at least 3 lifting and lowering tasks was added. This was accomplished by having the instructors repetitively perform simulated tasks, and having groups of 3-4 participants measure the task parameters. There was high interaction among the group members and participants, which clarified the operational measurement of the parameters. When participants wanted more practice, additional tasks were measured. This provided a feedback mechanism on actual measurement that was not provided in the original training class (although errors made by participants were discussed individually after the experiment).

The sensitivity analysis provides insight into the effect that measurement error can have on LI values. Unfortunately, the most sensitive parameters were the ones associated with some of the highest experimental errors. Reducing measurement error by 50% (Table 4) indicates that the most benefit can be achieved by reducing errors in frequency, horizontal location and weight. Reducing errors in measurement of weight can be achieved through the use of more accurate and precise instruments. Reducing errors in frequency and horizontal location can be achieved through better training and measurement strategies, as well as more careful measurement at the workplace.

3.5.1 Implications of Results

This study provides insight into the design of training programs for users of the 1991 NIOSH equation. Following the experiment, the participants were asked to provide feedback concerning the training program and the experiment. The comments tended to focus on feeling confident after the lecture, but being somewhat intimidated once the measurements began. This feedback, as well as the experimental results, led to improvements in the training program. The 'hands-on' portion of the class involving measurement of the individual parameters was partially subsumed into the lecture with the instructor demonstrating the measurements. The hands-on portion then became more like the experiment in that participants each demonstrated their ability to measure all parameters of simulated tasks. From these experiences as well as experiences with more diverse (with respect to education and job type) groups of users attending ergonomics short courses, it is recommended that strong emphasis is placed on actual measurement rather than lecture. Ideally, the most effective method is to visit a workplace and provide additional guidance and feedback to users. Several of the authors have used this approach with positive feedback.

Regardless of the training program used, the results indicate that measurement of horizontal location and frequency should receive priority. In fact, the magnitude of errors in the LI due to errors measuring horizontal location and frequency can make measurement errors in the other variables irrelevant for some tasks, i.e. a large error in frequency or horizontal location could be of the magnitude that the analysis will not be meaningful, regardless of other errors.

Comparison of the results of this study to those of Waters *et al.* (1998), which had more favorable results in some ways, provides interesting insight. The main differences between the two studies are Waters *et al.* (1998) used a training session almost twice as long (seven hours) as in the current study, only one task was measured, and frequency and duration were not measured. The results of the current study suggest that frequency is very important. The primary deficiency of the training program used for the current study was the lack of sufficient participation in measurements by subjects. Although the program has been modified to correct this problem, the results stress the importance of this type of training content in programs aimed at teaching users to correctly apply the equation. Given the results of both studies, and taking into consideration that the training was provided by individuals with expertise and experience applying the NIOSH equation, it is recommended that all users not familiar with measurements for the equation receive formal training.

3.5.2 Study Limitations

Several limitations of the study should be considered when interpreting the results. The first limitation is that five tasks were studied, all with the same box weight. Since the equation is multiplicative, errors can have differential relative effects for different weights. Also, these five tasks do not represent the full spectrum of industrial lifting and lowering tasks. Likewise, the sample of eight subjects does not represent the full spectrum of NIOSH equation users. Although all subjects had safety and health training, different results may have been obtained if the participants had either no or extensive training and experience. The latter two scenarios represent individuals that use the equation.

A critical issue that this study did not address is the broader issue of the impact of job analysis strategies on parameter measurement error. One of the most challenging aspects of using the NIOSH equation (and other task analytic MMH approaches) in industry is determining just what the individual tasks are, and then determining what the 'typical' parameter values are. In some cases, jobs are sufficiently complex such that defining distinct tasks is extremely difficult or impossible (e.g., warehousing, truck loading/unloading, complex palletizing operations where products frequently change). Similarly, workers rarely perform repetitions of a particular task in the same manner. One only needs to consider a layer of a pallet to be a distinct task to appreciate the variability in parameter values. In this case, parameters actually become variables. This issue could potentially be as or more important than parameter measurement error alone. Additionally, MMH guidelines such as the NIOSH equation may only be useful to experts with a real understanding of the limitations and underlying assumptions of the method being applied (Buckle *et al.*, 1992).

3.6 CONCLUSIONS

Based upon the results presented, as well as the authors' experiences with additional training sessions, the following conclusions can be made:

(1) Users of the NIOSH equation with MMH expertise should receive formal training.

(2) The length of training and/or the complexity of the tasks measured can affect users' ability to measure parameters.

(3) Due to the sensitivity of the LI to errors in frequency and horizontal location measurements, these parameters should receive priority when providing training. Additionally, these parameters are rather difficult to measure compared to the vertical locations (and hence distance traveled).

(4) The results illustrate the importance of testing a training program, and the current study provides an example of a methodology that can be used to test programs developed in the future.

4.0 DATA COLLECTION - PHASE I

4.1 GEOGRAPHIC LOCATIONS

Phase I of the data collection was conducted throughout the continental United States. This will provide a diversity of various factors such as industry type, jobs, and subject variables. The training of the 74 data collectors, which is described in the following section, was conducted in the locations listed below during the end of 1996. Individuals involved in collecting data were scheduled to attend the nearest location for training; thus, data collection was conducted in a wider range of sites than listed below.

Training sites:

Hopkinton, MA

Syracuse, NY

Irving, TX

Blue Bell, PA

Norcross, GA

Jackson, MS

Brentwood, TN

Orlando, FL

Pleasonton, CA

Orange County, CA

Novi, MI

Itasca, IL

4.2 DATA COLLECTOR TRAINING

Using the results of the pilot study and the validity study, a 4-hour training session was developed. The sessions involved approximately equal distribution of lecture and hands-on training. The lecture portion of the training session was based upon the data collection instructions discussed below. The hands-on training involved demonstrations and practice involving measuring the various task variables. Since horizontal distance and asymmetry are the variables requiring the most difficult measurements, these variables are given more attention.

4.3 DATA COLLECTION INSTRUCTIONS

The original version of the data collection instructions are provided in Appendix A. Each SHP was provided with a bound copy of the instructions.

4.4 SELECTION OF PARTICIPATING ORGANIZATIONS

The organizations being selected to participate have to be willing to allow SHPs to make the measurements and access OSHA logs, etc. Selection was primarily restricted to manufacturing facilities. Potential participants were told the reasons for the study and were informed of what their participation would require. Only those organizations with numerous MMH jobs were approached for participation.

4.5 JOB SELECTION

Job selection was restricted by the constraints of the study, e.g. the NIOSH equation only applies to certain settings. The criteria for job selection are discussed below.

The following exclusion criteria are being used to select jobs for the study:

a. Jobs where workers perform, on average, more than 15 lifts or lowers per minute. This criterion is necessary because the 1991 NIOSH equation does not apply to jobs where workers

b. Jobs where workers perform patient handling. Again, this is due to the restriction that the NIOSH equation is not applicable to these types of tasks.

c. Jobs with more than 15 distinct lifting/lowering tasks. This criterion was selected because we felt that jobs with many tasks would be difficult to model due to the uncertainty concerning how to weight the tasks.

d. Jobs which involve driving a vehicle. This criterion was selected because driving is a significant risk factor for low-back disorders. Including jobs involving significant driving components would make it very difficult to assess the contribution of MMH tasks to low-back disorder occurrence versus the contribution of the driving component.

e. Jobs involving seasonal work. This criterion was selected to reduce the possibility of exposure misclassification due to seasonal job demands.

The following inclusion criteria are being used to select jobs for the study:

a. Jobs with few component tasks. i.e., try to select jobs that have fewer distinct MMH tasks. This criterion was selected to reduce data collection costs. Additionally, simpler jobs make it easier to determine the contribution of individual tasks to injury risk.

b. Select jobs with the least day-to-day variety. We have to assume the data collected are representative of what the worker does every day, so this criterion was used to reduce exposure misclassification.

c. Jobs with multiple workers. This criterion was used since jobs with multiple workers are more efficient from the standpoint of data collection costs.

d. SHPs were instructed to select a variety of job types with respect to the MMH demands so that the criteria could be evaluated over a broad spectrum of job demands.

4.6 PERSONAL DATA

The personal data collected are shown on the personal data questionnaire shown in Appendix A. The informed consent used is also provided.

4.7 JOB AND TASK DATA

The job and task data are being collected using the forms in Appendix A. Each of the variables being collected are indicated on the forms. These forms were developed prior to the pilot study and have been redesigned using feedback from the SHPs that participated in the pilot study.

4.7.1 Data Collection Apparatus

Many of the MMH task variables measured and recorded require the use of measuring instruments. SHPs were provided with a spring scale to measure object weights and pushing and pulling forces, a tape measure to measure various workplace and task variables, and a protractor with reference guides to measure asymmetry.

4.8 DATA COLLECTION PROBLEMS

4.8.1 Applicability of the 1991 NIOSH Equation

A serious barrier to data collection has been problems associated with the restrictions on the use of the 1991 NIOSH equation. If the restrictions given by Waters *et al.* (1994) were followed to the letter, almost no jobs would be appropriate for the use of the NIOSH equation. Among the prominent problems are one-handed lifting and frequency violations. Although Waters *et al.*

(1994) indicate that jobs involving other materials handling tasks, such as holding for more than a few seconds or carrying more than one or to steps, should not be evaluated with the NIOSH equation. This restriction could not be followed because many jobs involving MMH have activities besides lifting or lowering.

A related issue is that the job selection criteria are rather restrictive. This has made it difficult to find jobs that satisfy the criteria. These restrictions were instituted to ensure that the frequency, duration, and magnitude of exposure were captured.

4.8.2 Miscellaneous Problems

One problem that has been encountered is that of unions not wanting their membership to participate because participation is voluntary. This is unfortunate, but is a reality of labor-management relations that must be considered.

A problem has been that many facilities visited thus far have had only a few jobs that qualify for inclusion. To remedy this situation, larger organizations with repetitive tasks performed in multiple sites were solicited for participation at the corporate level. This approach facilitated data collection.

4.8.3 Remedial Measures to Facilitate Data Collection

In order to assess the technical reasons for why data collection was not progressing as rapidly as expected, a survey tool was developed to gather information on jobs that were not analyzed. Reports from those trained to collect data indicated that many organizations agreed to participate, but that the jobs in the facilities were not suitable for the study. Information was gathered on the nature of these jobs, and this information was used to create the survey shown in Figure 2.

SHPs were asked to fill out the survey in Figure 2 for each job that was examined, but not included in the study. These surveys were completed for several months, and a total of 40 jobs were examined. Table 5 provides a summary of the results. Overall, the results indicate that the content of the jobs was too dynamic to be studied. A major problem was that of weights being too variable to perform a reasonable exposure assessment.

Figure 2. Survey form for jobs not suitable for study.

Name____________________ Office____________________ Date________

Customer______________________________

Facility Location___________________

SIC Code______________________________

Willing to participate Yes ❑ No ❑

If no, why?____

____

Job Title______________________________

Was Job Examined Acceptable? Yes ❑ No ❑ If yes, date sent to LMRC____________

If No, Why not? (check ALL that apply)

Job Rotation ❑	No 2-handed lifting ❑
Too many tasks to analyze ❑	Workers not willing ❑
Weights/tasks change ❑	Job changes often ❑

Other____

Table 5. Summary of 40 jobs not suitable for study

Category	Percent Jobs
Weights variable (> 10 lbs)	62.5%
Job changes often	25%
Job Rotation	22.5%
Too many tasks to analyze	22.5%
No 2-handed lifting	15%
Frequency too high	15%
Workers not willing	2.5%
Language barriers	2.5%

A brief summary of the data also revealed that some of the observations violate restrictions of the NIOSH equation. This included: (1) 32% of acceptable observations exceed 8-hour limit, (2) 52% of observations include significant "other" tasks, and (3) 25.2% of observations do not have a valid LI. However, these violations were necessary since the sample size would be drastically reduced.

5.0 DATA COLLECTION - PHASE II

5.1 REVISED DATA COLLECTION PROTOCOL

The problems finding suitable jobs for inclusion in the study (see 4.8.3) prompted a major revision to the data collection protocol. In order to provide a protocol capable of assessing a higher percentage of MMH jobs, protocols were added to address warehousing jobs (and other jobs with very high numbers of distinct tasks), jobs with rotation, and jobs with variable weights. The revised instructions and data collection protocols are shown in Appendix A..

Three additional training classes with 10 participants were conducted in the sites listed below:

Training sites:

Hopkinton, MA

San Antonio, TX

Blue Bell, PA

Additionally, five members of the Research Center and the Director - Ergonomics and Manufacturing technology were involved in data collection.

5.2 DATA COLLECTION PROBLEMS

In spite of the revised data collection protocol, problems were still encountered. Although the new protocols allowed more jobs per facility to be included, limitations on the scope of the NIOSH equation limited data collection. A brief summary of the use of the revised protocols is as follows:

(1) Warehouse/Complex Protocol: This was clearly the most widely used of the new protocols. In fact, many MMH jobs observed during 1999 were fairly complex from the standpoint of the number of tasks, variety of materials handled, etc. One of the most useful observations noted during the study is that future assessment methods need to focus on the ability to analyze such exposures.

(2) Job Rotation Protocol: This protocol was not used extensively. In several cases, the job rotation schemes in the facilities visited were not regular. In some cases, the rotation occurred in almost arbitrary manners, with rotations depending on staffing for a particular day. This was particularly true in several facilities that had workers that rotated jobs in order to fill in for absences, vacations, etc.

(3) Variable Weight Protocol: The variable weight protocol was also not used extensively. For many of the jobs with variable weight demands, all the parameters of the lifting tasks tend to change as weight changes. For example, horizontal location tends to be partially dependent on the dimensions of the load, frequency tends to vary with the magnitude of the load, etc. In fact, the sampling procedure for the warehouse/complex protocol was applied to several amenable jobs of this nature.

Below are several examples of why data collection efforts during 1999 were not completely successful.

- Producer of systems and components for nonresidential structures - 8 locations

Three locations were visited, resulting in three subjects being added to the study, all from the same location. Unfortunately, numerous jobs involving materials handling did not involve two-handed lifting or lowering that could be analyzed with the NIOSH equation. Many jobs involved lifting or lowering items that were partially supported on a surface, team lifting, and one-handed lifting. Managers from two of the locations that were not visited were contacted and they indicated that similar jobs would be found in those facilities.

- China manufacturing - 3 locations

Three locations were visited and 25 subjects were added to the study. Numerous jobs were examined but not analyzed due to highly variable activities. In some cases, lifting was almost exclusively of partially supported molds, so the equation was not applicable. The actual job required more material manipulation than material handling.

- Printer - 1 location

This facility was visited and four jobs were examined, but none had manual handling tasks that could be analyzed with the NIOSH equation.

Overall, most facilities did not have enough exposures that fit the exposure assessment protocol, including the revised protocols for variable weight, job rotation, and warehouse/complex jobs to be economical. Likewise, the problems of finding jobs for the study resulted in the slow data collection process. Although we fine-tuned our ability to solicit cooperation, the major limiting factor was the number of viable jobs in facilities that have agreed to participate. The entire process of soliciting facilities and workers to volunteer, scheduling visits, and making data collection visits was quite involved and personnel-intensive.

5.3 PROSPECTIVE FOLLOW-UP PROCEDURES

All active participants in the study are sent a letter and brief survey four times a year. The survey is shown in Figure 3. The survey asks if they are still doing the same job as when they enrolled in the study. If not, they are asked what date they stopped performing that job, and why. Participants are also asked if they have been injured at work, and if they have been out of work for more than three weeks at a time. Subjects are provided with a pre-paid envelope to return the questionnaire, and as an incentive are included in a prize drawing if surveys are returned on time.

If a subject is longer doing that job and provides the date they stopped, they are sent a letter thanking them for their participation, and removed form the active mailing list. Subjects can also be removed from the active list if their workers' compensation history is not available. In this case, the last insured date for the company is used as the last exposure date. Otherwise, participants remain on the mailing list and continue to receive the quarterly mailings.

Further attempts are made to contact those subjects who do not respond to the mailings. Twice a year participants who fail to return the survey after three weeks are sent a reminder, and another copy of the survey. On the other two occasions, an attempt is made to contact non-respondents by telephone. This includes calling directory assistance for non-working numbers, and searching internet databases for potential matches.

Contact is also maintained with participating companies. Once a year a newsletter detailing progress on the project and other MMH related content is sent to each workplace. A list of participants who cannot be contacted is also sent to each company contact. We ask the company to confirm that these employees are still doing the job as evaluated, and if not what date they stopped.

The SHPs who have contact with the participating companies are asked to obtain the OSHA 200 logs from participating sites on an annual basis. Several problems have been encountered, particularly when the company contact that was involved in the study is no longer with the company or in the same job. Several facilities are also exempt from keeping the OSHA 200 log. The workers' compensation information is retrieved annually.

Figure 3. Follow-up survey for obtaining prospective information.

Follow-Up Survey

Interview Date: 1/1/97

Name: John Doe
Address: 15 Main Street
Metropolis MA 33333
Telephone: 555-1212
Work Shift: 1
E-mail? ____________

Please print any changes to personal information (name, address, phone #) below.
Name ____________
Address ____________
____
Phone # ____________
Shift ____________

Job: Materials Handler at Manufacturing Company

1. Are you still doing the above job as of ___/___/___ (please write in today's date)?
☐ yes ☐ no

If no, when did you stop working as a(n) Materials Handler? (date stopped) __/__/__
If no, why did you stop working on this job? (Please check an answer below.)

☐ Job transfer ☐ Injury
☐ Job re-designed ☐ Other ____________ (write in)
☐ Laid off

2. Since 6/15/97 , have you been injured at work? ☐ yes ☐ no
If yes, please write below the type of injury you had (e.g. sprain), part of body hurt and date of injury.

Type of Injury	Body Part	Date
____________	____________	__/__/__
____________	____________	__/__/__

3. Since 1/1/97, have you been out of work for more than 3 weeks at a time? ☐ yes ☐ no
If yes, please complete below:
reason: ____________ from dates __/__/__ to __/__/__
reason: ____________ from dates __/__/__ to __/__/__

Thank you for completing this survey. This survey must be fully completed to be eligible for the raffle.

Please return in the enclosed, postage paid envelope to:
393 **Liberty Mutual Research Center, 71 Frankland Road, Hopkinton, MA 01748**

6.0 DATA ANALYSIS

Appendix C contains a listing of n=444 cases for which valid LIs are calculated. Of these 444, only n'=406 had positive exposure hours; the remaining 38 cases either left the study immediately, or had not had follow-up assessment at the time of writing this report. In the descriptive analyses we include all 444 subjects as representing our "intent to observe" population. For relating outcomes to predictors, only the 406 subjects with positive exposure hours are included.

All statistical analyses are performed using the SAS/STAT® software, version 8.0.

6.1 SUMMARY OF SUBJECT DATA

The following tables display summary statistics for the subjects. Table 6 illustrates the descriptive statistics of female workers obtained from the worker survey. For simplicity, the values in the table are rounded up to two decimal places. The subject height is measured in inches and the weight is measured in pounds. The age of the subject is calculated by dividing the number of days between the initial interview date and the subject's date of birth by 365.25. Thus, the calculated age is in decimal places. The average number of hours each subject works per day includes lunch break.

Table 6. Descriptive statistics of female subjects.

Variable	N	Mean	Std Dev	Minimum	Maximum
Height (inches)	138	64.39	3.38	48	76
Weight (pounds)	122	148.89	31.18	100	280
Age (at entry into study)	135	37.03	9.50	19.54	59.89
Hours worked per day	139	8.24	1.44	3	12

Table 7 shows the descriptive statistics for the male workers. It can be seen that the average height and weight of the male workers are greater than that of female workers. Female subjects are slightly older than male subjects (37 versus 34 years). The number of hours the male workers work per day is approximately the same as that of the female workers.

Table 7. Descriptive statistics of male subjects.

Variable	N	Mean	Std Dev	Minimum	Maximum
Height (inches)	309	69.82	3.17	60	81
Weight (pounds)	309	187.54	35.97	115	308
Age (at entry into study)	306	34.09	9.92	18.10	62.18
Hours worked per day	310	8.18	1.20	2.5	12

Numerous jobs were included in the study. These selected jobs were required to have a primary lifting and lowering component. Each job might have different exposures to different task compositions. For example, one job might require more lifting than pulling and another might require more lowering and carrying. Listed in Table 8 are the frequencies for the most common jobs included in this survey.

Table 8. Numbers and percents of workers in the most frequent jobs.

Job Title	Frequency	Percent	Cumulative
Packer	36	8.22%	8.22%
Operator	27	6.16%	14.38%
Material Handler	21	4.79%	19.18%
Stocker	18	4.11%	23.29%
Bundler	18	4.11%	27.40%
Stock Handler	15	3.42%	30.82%
Caster	13	2.97%	33.79%
Shipper/Receiver	13	2.97%	36.76%
Machine Operator	13	2.97%	39.73%
Shipper	12	2.74%	42.47%
Forklift Operator	11	2.51%	44.98%
Loader	10	2.28%	47.26%

According to the survey, 4.7% of the subjects responded that they had filed a workers' compensation claim during the past 12 months because of back pain (Table 9). The majority of the workers, however, responded that they did not file a workers' compensation claim during the past 12 months.

Table 9. Frequency table for workers' compensation claim.

Prior worker* compensation	Frequency	Percent	Cumulative Frequency	Cumulative Percent
No	425	95.3	425	95.3
Yes	11	4.7	446	100.0

* No = No compensation claim filed, Yes = compensation claim filed

In the survey form, subjects were asked whether or not they exercise on average three or more times per week outside of work and, if so, what type of exercise that they do. Table 10 shows that 55.6% of the workers gave a positive response and the rest 44.4% responded that they do not exercise regularly.

Table 10. Frequency table for regular exercise.

Exercise	Frequency	Percent	Cumulative Frequency	Cumulative Percent
No	247	55.6	247	55.6
Yes	197	44.4	444	100.0

Table 11 shows that out of 447 subjects surveyed, 336 workers responded in the survey that they do not wear a back belt while doing the assigned job. This makes up about 75% of the total workers surveyed. The other 25% responded that they have worn a back belt while performing their jobs.

Table 11. Frequency table for wearing back belt.

Backbelt	Frequency	Percent	Cumulative Frequency	Cumulative Percent
No	336	75.2	336	75.2
Yes	111	24.8	447	100.0

Table 12 shows the comparison of weighted lifting index between subjects who had and had not filed a workers' compensation claim during the past 12 months because of back pain. A total of 21 subjects responded that they had filed a worker's compensation claim while 420 did not. The mean of weighted LI91 (1991 lift index time-weighted by task group as described in section 6.3) of injured workers was found to be 13% greater than those who were uninjured.

Table 12. Descriptive statistics of weighted LI91.

	Weighted LI				
Prior worker* compensation	N	Mean	Std Dev	Minimum	Maximum
No	420	4.08	5.36	0.13	39.05
Yes	21	4.60	5.24	0.67	21.02

* No = No compensation claim filed, Yes = compensation claim filed

6.2 SUMMARY OF JOB DATA

The following table provides summaries of parameters relating to lifting stress. The data are accumulated over all subjects, task groups, and tasks within task groups.

Table 13. Summary of job parameters.

Variable	N	Mean	Std Dev	Minimum	Maximum
Object weight (pounds)	3946	25.14	15.6	1	100
Starting vertical position (in)	3946	35.32	13.91	1	90
Ending vertical position (in)	3946	35.35	14.48	1	84
Starting horizontal position (in)	3946	17.59	5.17	5	49
Ending horizontal position (in)	3946	19.04	5.39	5	45
Starting angle of asymmetry	3946	19.92	20.83	0	110
Ending angle of asymmetry	3946	18.98	19.07	0	110
Lifting Frequency (lifts/minute)	3946	3.36	3.13	0.01	15

To facilitate data collection and thereby increase sample size, we decided during the course of the research to use measured job characteristic data from one worker to apply to all workers holding the same job. The warehousing jobs in particular have several such duplications. There is some concern about using such duplicated observations in the summaries of Table 13. Table 14 shows the same statistics, excluding jobs that are duplicates. (There are 166 unique jobs in the study).

Table 14. Summary of numerical job parameters using 166 unique jobs. Sample sizes are higher than 166 because there are typically multiple task groups and tasks within groups per job.

Variable	N	Mean	Std Dev	Minimum	Maximum
Object weight (pounds)	1100	24.97	14.66	1	100
Starting vertical position (in)	1100	34.92	13.68	1	90
Ending vertical position (in)	1100	34.73	14.26	1	84
Starting horizontal position (in)	1100	16.95	5.36	5	49
Ending horizontal position (in)	1100	18.24	5.75	5	45
Starting angle of asymmetry	1100	17.29	21.52	0	110
Ending angle of asymmetry	1100	19.47	21.3	0	110
Lifting Frequency (lifts/minute)	1100	2.66	3.16	0.01	15

The summaries are similar in Table 13 and Table 14; however, since a large proportion of the repeats are warehousing jobs with higher pick frequencies, the average frequency is higher in the complete data set where the warehouse data is weighted more heavily.

We also include tables of frequencies for qualitative job parameters as follows in Tables 15 and 16.

Table 15. Summary of qualitative job parameters.

		Frequency	Percent
Duration	Long	3625	91.87
	Med	140	3.55
	Short	181	4.59
	Total	3946	

		Frequency	Percent
Coupling	Fair	3199	81.07
	Good	124	3.14
	Poor	623	15.79
	Total	3946	

		Frequency	Percent
Significant Control	No	3157	80.01
	Yes	789	19.99
	Total	3946	

Table 16. Summary of qualitative job parameters using 166 unique jobs.

		Frequency	Percent
Duration	Long	902	82
	Med	71	6.45
	Short	127	11.55
	Total	1100	

		Frequency	Percent
Coupling	Fair	837	76.09
	Good	78	7.09
	Poor	185	16.82
	Total	1100	

		Frequency	Percent
Significant Control	No	753	68.45
	Yes	347	31.55
	Total	1100	

6.3. LIFT INDEX CALCULATIONS

6.3.1 Calculation of the AL, RWL, LI_{81} and LI_{91}.

The AL and RWL calculations are (NIOSH, 1981; Waters *et al.*, 1993b):

$$AL = 40\,\text{kg.}*\left[\frac{15}{H}\right]*\left[1-.004|V-75|\right]*\left[.7+\frac{7.5}{D}\right]*\left[\frac{F}{F_{MAX}}\right]$$

$$RWL = 23\,\text{kg.}*\left[\frac{25}{H}\right]*\left[1-.003|V-75|\right]*\left[.82+\frac{4.5}{D}\right]*FM*\left[1-.0032*A\right]*CM$$

Where:

H = Horizontal distance (cm.) from the ankles to the hands at the origin and destination of the load.

V = Vertical location (cm.) of the load at the origin and destination of the lift/lower.

D = Vertical distance (cm.) the load travels.

F = Frequency of the lift in lifts/minute.

F_{MAX} = Value determined from table in NIOSH (1981).

FM = Frequency multiplier from table in Waters *et al.* (1993b) using extrapolations for cases not in the table.

CM = Coupling multiplier determined according to the definitions given by Waters *et al.* (1993b).

A = Angle of asymmetry at the origin and destination of the lift.

The AL and RWL are calculated for both the origin and the destination of the load for each task as described by NIOSH (1981) and Waters *et al.* (1993). The lower of each of these two sets of values is used as the AL and RWL for that task, respectively.

The LI_{81} and LI_{91} values are defined as:

$$LI_{81} = \frac{\text{Actual load}}{AL} \qquad LI_{91} = \frac{\text{Actual load}}{RWL}$$

6.3.2 Calculation of Composite Lifting Indices

Most tasks analyzed consist of several lifting/lowering tasks, such as palletizing operations. For these tasks, a single LI is be needed for the statistical analyses. Although there were no multi-task procedures for the 1981 equation (NIOSH, 1981), multi-task procedures have been developed for the 1991 equation. The following multi-task procedures is used for both the 1981 and 1991 equations so that the results of the statistical procedures are comparable. (In what follows the procedures are discussed using only the 1991 equation for simplicity).

Three separate methods for computing composite lifting indices are discussed below.

6.3.2.1 Waters et al. *(1993a) Method*

This method involves the following steps (Waters *et al.*, 1993a):

1. Calculate Frequency-Independent Recommended Weight Limits (FIRWL) for each task. The RWL given above is calculated using a FM value of 1 to obtain the FIRWL.
2. Calculate the Frequency Weighted Recommended Weight Limits (FWRWL) for each task, where:

$$FWRWL = \frac{\sum(FIRWL_i * F_i)}{\sum F_i}$$ where F is the task frequency and *i* is the task number.

3. Calculate the Composite Recommended Weight Limit (CRWL):

$$CRWL = FWRWL * FM_{Job}$$ where FM_{Job} is determined for the overall frequency and duration of the job from the frequency multiplier table.

4. Calculate the LI for each job by dividing its load weight by the CRWL for the job.
5. This methods provides a LI for each task, however, the statistical analyses require that each job has only 1 LI. To accommodate this, the following revision to this method is used:

$$CLI = \sum_{i=1}^{n} \frac{Hours_i * LI_i}{Hours_t}$$

Where:

n = number of tasks LI_i = LI for task *i*.

$Hours_i$ = hours spent performing task *i*. $Hours_t$ = Hours worked per day.

6.3.2.2 Waters et al. (1994) Method.

This method involves the following steps (Waters *et al.*, 1994):

1. Compute the FIRWL as described in the preceding discussion.
2. Compute the Single-Task Recommended Weight Limit (STRWL) for each task. This is accomplished by multiplying the FIRWL for each task by its FM value obtained from a table.
3. Compute the Frequency-Independent Lifting Index (FILI) and Single-Task Lifting Index (STLI) for each task where:

$$FILI_i = \frac{\mathrm{Load}_i}{FIRWL_i} \qquad STLI_i = \frac{\mathrm{Load}_i}{STRWL_i}$$

4. Compute the Composite Lifting Index:
   a. The tasks are numbered in descending order of $STLI_i$.
   b. The CLI is computed according to the following formula:

$$CLI = STLI_1 + \left[FILI_2 * \left(\frac{1}{FM_{1,2}} - \frac{1}{FM_1} \right) \right] + \left[FILI_3 * \left(\frac{1}{FM_{1,2,3}} - \frac{1}{FM_{1,2}} \right) \right] + \cdots$$
$$+ \left[FILI_n * \left(\frac{1}{FM_{1,2,3 \ldots n}} - \frac{1}{FM_{1,2 \ldots (n-1)}} \right) \right]$$

The numbers in the subscript refer to the ordered task numbers and the FM values, determined from the table, are based on the sum of the frequencies for the tasks listed in the subscripts.

6.4 INJURY OUTCOME DATA

There were 10 observed back injuries in the course of the prospective study. Despite the rather small number of incidences, a trend seems apparent, both in relation to LI91 and to LI81. Table 17 shows the categorizations, excluding cases with zero exposure hours.

Table 17. Tabulation of injury outcomes for different LI categories.

Injury	LI91 category				
Frequency Col Pct	<1	1-2	2-3	>3	Total
No	61 98.39	117 99.15	66 94.29	152 97.44	396
Yes	1 1.61	1 .085	4 5.71	4 2.56	10
Total	62	118	70	156	406

Two-sided Cochran-Armitage trend p-value = 0.3982 (exact)

Injury	LI81 category				
Frequency Col Pct	<1	1-2	2-3	>3	Total
No	119 99.17	166 97.65	70 95.89	41 95.35	396
Yes	1 0.83	4 2.35	3 4.11	2 4.65	10
Total	120	170	73	43	406

Two-sided Cochran-Armitage trend p-value = 0.0915 (exact)

Note that the percentage of injuries appears higher with larger LI's. Interestingly, the trend seems more consistent (and more significant) with LI81. Also, note that there are fewer LI81 values in the upper ranges, because LI91 tends to produce larger index values.

It is also customary to report injuries per 200,000 exposure hours (or per 100 FTE as defined by OSHA). These data are given in Table 18.

Table 18. Tabulation of injury outcomes per 100 FTE for different LI categories.

L191 Category

	0 ≤ LI < 1	1 ≤ LI < 2	2 ≤ LI < 3	LI > 3
Exposure Hours	195,811	207,146	196,538	316,913
# Injuries	1	1	4	4
Rate/100 FTE	1.02	0.97	4.07	2.52

L181 Category

	0 ≤ LI < 1	1 ≤ LI < 2	2 ≤ LI < 3	LI > 3
Exposure Hours	353,504	318,019	172,379	72,506
# Injuries	1	4	3	2
Rate/100 FTE	0.57	2.52	3.48	5.52

The estimated injury trend in rate per 100 FTE is more pronounced for the LI81 measure, but since the data are so sparse, we cannot necessarily conclude that the LI81 measure is more predictive of LB injury.

7.0 PREDICTION MODELS RELATING INJURY OUTCOMES TO SUBJECT AND JOB DATA

The goal of the research was to model the injury probability function using LI81 or LI91, or alternative forms involving job parameters, and to include personal covariates. Given the lack of observed injuries, and the very marginal significances shown in Table 17, it is not possible to assess such effects with much precision. Nevertheless, the data suggest some interesting effects as we discuss below.

7.1 SIMPLE LOGISTIC REGRESSIONS USING LI81 AND LI91.

Tables 17 and 18 display trends as a function of the discretely categorized LI responses. There are many LI's in the higher ranges: as shown in Table 12, the maximum of LI91 is 39.05. There is therefore loss of information when making the responses discrete. In this section we consider simple logistic regression models for injury probability as a function of LI91 or LI81 (see Table 19).

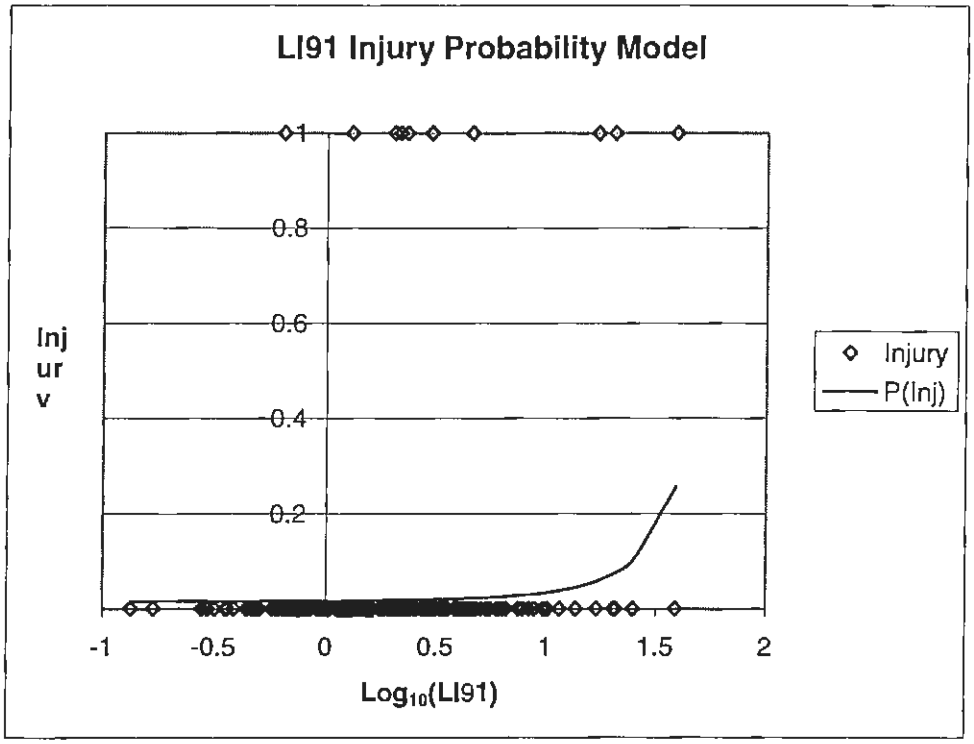
Table 19: Logistic regression results for LI91.

```
Analysis of Maximum Likelihood Estimates

                                    Standard
Parameter    DF    Estimate           Error    Chi-Square    Pr > ChiSq

Intercept     1     -4.1445          0.4108      101.7746        <.0001
LI91          1      0.0789          0.0299        6.9913        0.0082


R-Square     0.0122
Max-rescaled R-Square     0.0594

                         Odds Ratio Estimates

                           Point          95% Wald
             Effect     Estimate      Confidence Limits

             LI91          1.082        1.021       1.147

 Estimated Model:  ln(p/(1-p)) = -4.1445 + 0.0789LI91, where p = injury probability
```

Note that, in contrast to the Cochran-Armitage trend test shown in Table 17, the trend is significant using the logistic regression model. The odds of injury are increased by an estimated 8.2% per unit increase in LI91, with a 95% confidence range from 2.1% to 14.7%.

Figure 4 shows the observed LI91 and injury data, as well as the logistic regression model.

Figure 4. LI91 data and logistic regression model.



The model (see Table 20) appears not as significant as the LI91 model, but the odds ratio is estimated at a higher value. This seeming inconsistency is explained by the fact that the LI81 range is less, as shown in Figure 5.

Table 20: Logistic regression results for LI81.

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	-4.0968	0.4072	101.2105	<.0001
LI81	1	0.1538	0.0664	5.3650	0.0205

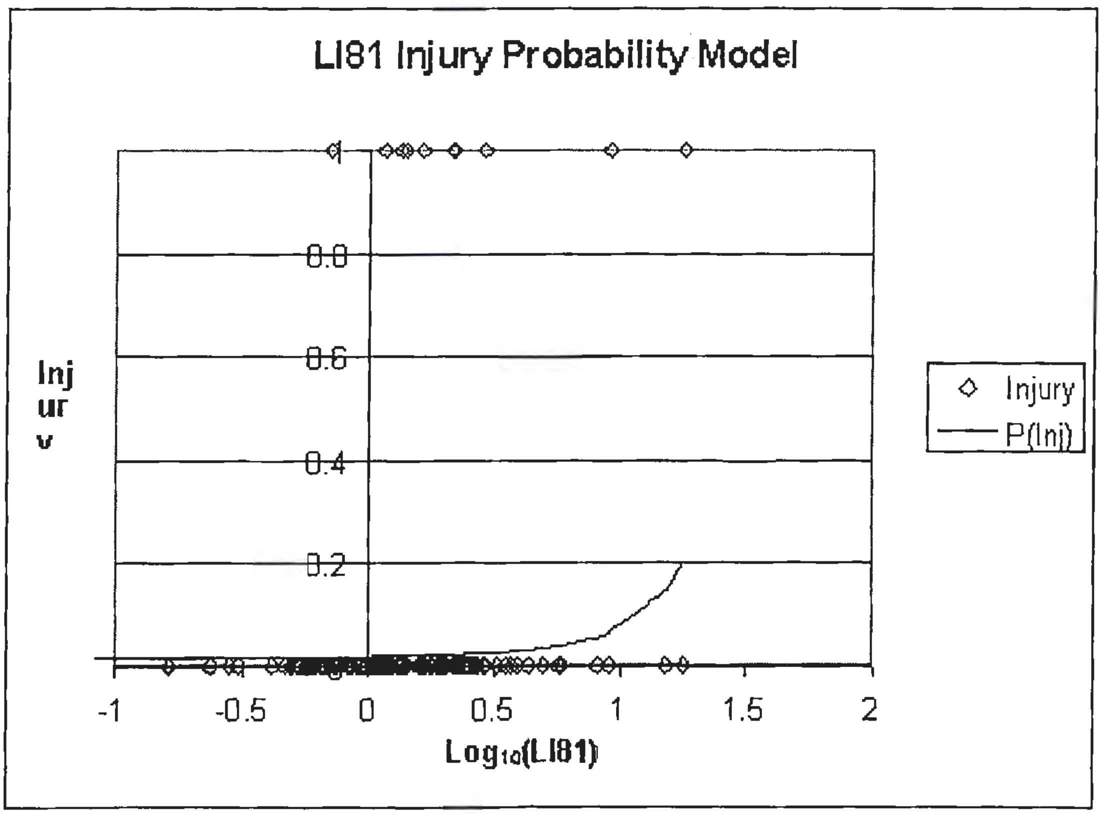
R-Square 0.0092
Max-rescaled R-Square 0.0447

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
LI81	1.166	1.024	1.328

Estimated Model: ln(p/(1-p)) = -4.0968 + 0.1538LI81, where p = injury probability

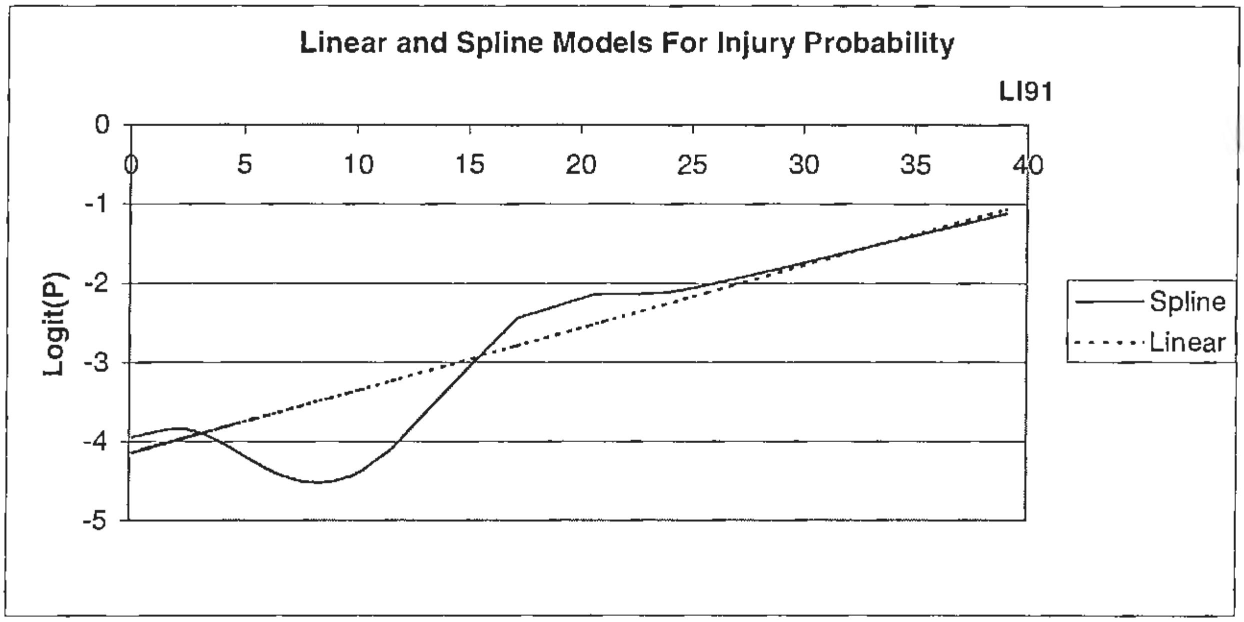
Figure 5. LI81 data and logistic regression model.



7.2 FLEXIBLE (NONLINEAR) LOGISTIC REGRESSION MODELS

One of the initial goals was to assess nonlinear affects through flexible (spline-based) logistic regression models. Such are implemented in the statistical package "SPLUS". Figures 6 and 7 show how the flexible logistic regression model compares with the simple linear logistic model.

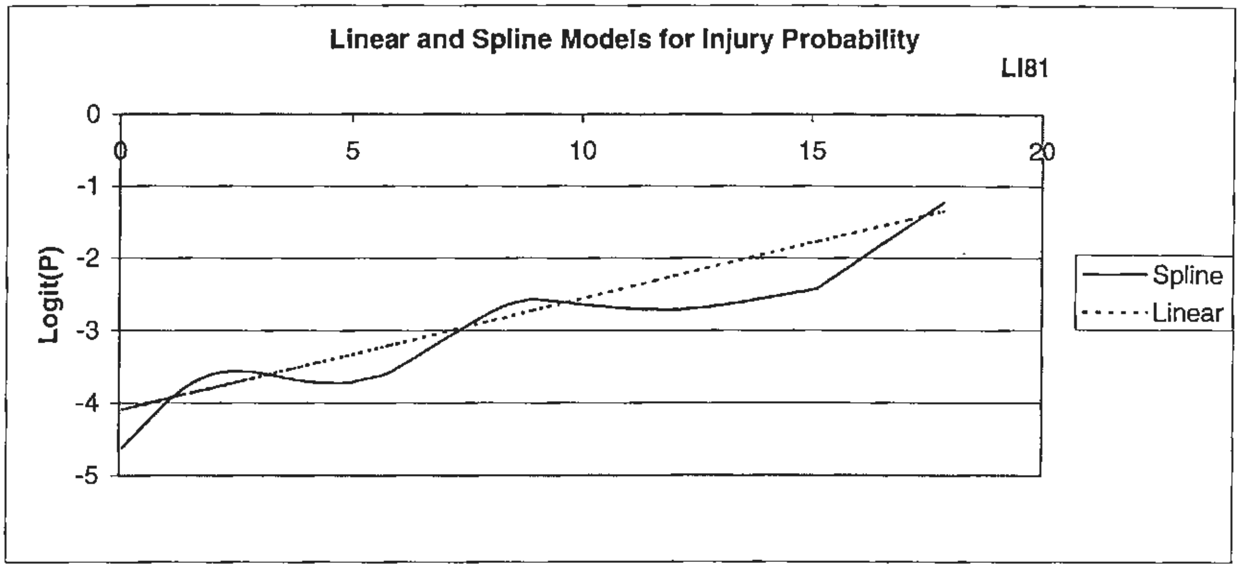
Figure 6. Comparison of linear and spline models for LI91.



The unusal "dip" in the spline model is explained by the LI91 values for the 10 injured subjects: They are (see Appendix C) 0.64, 1.30, 2.04, 2.16, 2.32, 2.98, 4.56, 17.21, 20.52 and 39.05. The "dip" corresponds to the gap between 4.56 and 17.21. No statement concerning general validity of the "dip" is made: it is probably sample-specific phenomenon caused by low number of observed injuries.

The corresponding analysis of LI81 is shown below:

Figure 7. Comparison of linear and spline models for LI81.



The "wavy appearance" in this spline model is explained by the LI81 values for the 10 injured subjects: They are (see Appendix C) 0.69, 1.14, 1.32, 1.39, 1.62, 2.12, 2.15, 2.86, 8.95 and17.87. The two "dips" correspond to gaps (2.86 to 8.95) and (8.95 to 17.87) . Again, no statement concerning general validity of the "dips" is made: they probably sample-specific phenomena caused by low number of observed injuries.

In both the LI81 and LI91 models, the linear approximation is adequate. Deviations from linearity shown in Figures 6 and 7 are attributable to low number of injuries.

7.3 EVALUATION OF EXTENT THAT SUBJECT MODIFIERS CAN BE ENTERED INTO THE EQUATION

As previously noted, our ability to detect subject-specific modifiers to the probability of injury is limited by the low frequency of injury occurrences. For both of the linear logistic regression models for injury (using both LI91 and LI81), we considered forward selection of additional factors among the set of variables GENDER, HEIGHT, WEIGHT, AGE, and EXPOSURE HOURS. None contributed additional significance to the model at the 5% level. Relaxing the significance for entry criterion to 50%, we find that WEIGHT enters both models with a coefficient of -.007 or -.008

(depending on the model). Although this effect is not significant, the estimate suggests that the odds of injury are reduced by 7% when workers are 10 pounds heavier.

7.4 COX MODEL

Noting that the analysis of the previous section found no significant effect of exposure hours in the logistic regression model, it is not expected that a survival analysis of time until injury will provide substantially different conclusions. Nevertheless, we report such results here for completeness, as they were part of the initial deliverables for the research grant.

The response variable is time until injury. Note that all but the 10 injury occurrences are treated as censored observations, with censoring times given by the exposure hours (see Table 20a and b).

Table 20a: Cox regression model results for predicting time until injury. Coefficient of LI91 is effect on log hazard.

Variable	DF	Parameter Estimate	Standard Error	Chi-Square	Pr > ChiSq	Hazard Ratio
LI91	1	0.10276	0.03373	9.2798	0.0023	1.108

Estimated Model: $\ln(\lambda) = C + 0.10276\text{LI91}$, where λ = hazard function, and C = baseline hazard

Table 20b: Cox regression model results for predicting time until injury. Coefficient of LI81 is effect on log hazard.

Variable	DF	Parameter Estimate	Standard Error	Chi-Square	Pr > ChiSq	Hazard Ratio
LI81	1	0.23738	0.07244	10.7380	0.0010	1.268

Estimated Model: $\ln(\lambda) = C + 0.23738\text{LI81}$, where λ = hazard function, and C = baseline hazard

The conclusions agree with those of the logistic regression in that significant effects are found, but the degree of significance flip-flops when comparing LI91 and LI81. In the analysis of hazards, the LI81 model appears more significant. However, with so few occurrences, this conclusion should not be considered generalizable.

7.5 SEVERITY ANALYSIS

At the time of writing this report, severity analysis is not available. We expect that such information will be available in the future and will appear in follow-up research reports of Liberty Mutual and Texas Tech University in regards to this study.

8.0 DISCUSSION

8.1 PROGRESS ON ACHIEVING SPECIFIC AIMS

1.) To prospectively determine if the LI for jobs from various industries is related to the incidence and severity of low-back disorders.

While the data are sparse, a statistically significant prospective relationship between LI (both 81 and 91) appears to be confirmed. See Sections 7.1 and 7.4.

2.) To prospectively determine if the relationship between the LI value and probability of low-back injury is different for workers of different sex, age, height, weight, and history of prior low-back pain or injury episodes.

Due to sparseness of the data, statistically significant modifiers of LI effects are not found. The only variable that comes close to significance is subject weight, which shows an estimated decreasing effect on injury probability, although it is not nearly statistically significant. See Section 7.3.

3.) To compare the current functional forms of the four multipliers that are continuous (i.e. VM, HM, DM, AM as defined by Waters *et al.* (1993)) to empirically determined relationships between V, H, D, and A and the incidence of back injuries

These relationships cannot possibly be uncovered with only 10 injury occurrences. Data collection difficulties have precluded the successful completion of this aim. We have attempted to assess whether the more flexible spline-based models will be preferred to the linear predictors (see Section 7.2) but the results are inconclusive, and we choose to retain the linear model for this study, mainly for the sake of parsimony.

4.) To determine if an alternate injury prediction model developed from the data collected that incorporates the 6 variables currently represented in the RWL equation, personal variables, job-related factors, and their interaction terms would be more appropriate than the NIOSH equation or useful as a supplement

We have attempted to address this to a degree by comparing LI81 with LI91. Again, we find that the lack of injuries hampers our ability to make firm conclusions. In two formal analyses, the LI81 model appeared to be a better predictor (the categorical data analysis of Section 6.3 and the proportional hazards analysis of Section 7.4), while in the simple logistic regression analysis, the LI91 model appeared to be a better predictor (see Section 7.1).

We have also noted mild evidence of non-linear increases in injury probability as a function of LI91 also noted by Waters et al (1999), who noted a decrease in injury probability for LI>3 (Table 4 of Waters et al.) We found similar, corroborating evidence (see the LI91 results in Table 13 and in Figure 3), although the sample size is too small to make a strong conclusion. Such a decrease might be explained by selection effects: workers selected for stressful lifting duties (or who themselves have selected such duties) probably have stronger backs.

We do not notice such nonlinear effects when using the LI81 index (see Table 13 and Figure 4), however.

5.) To qualitatively evaluate the usability of the new equation in practical situations

The results presented provide an overview of various usability issues associated with the revised NIOSH equation. In summary, there are various levels of usability that were assessed. At the most basic level, the parameter ranges and certain restrictions were examined with field data. At a broader level, the usability of the equation was examined from the standpoint of the ability to perform assessments of MMH jobs with the equation. Each of these constructs is discussed in more detail below.

5.1. Scope and limitations of equation

The data presented earlier indicate that about one third of MMH tasks have one or more parameter values that exceed the acceptable ranges. In these cases, the associated multiplier becomes 0, the RWL is 0, and the LI becomes infinite. In reality, the task does not pose infinite risk simply because the parameter exceeds the limit. In these situations, the highest value the multiplier accepts can be used, or in some cases, the multiplier will actually accept higher values. In both cases, the fact that the parameter exceeds the bounds is often a signal of poor workplace design and can be considered an assessment result in and of itself.

If one were to carefully assess all the restrictions above before applying the equation, few MMH exposures (at least in the United States) are amenable to analysis with the NIOSH equation. The tasks analyzed for the present study are biased since primarily lifting and lowering jobs and simpler jobs (in terms of the number of distinct tasks) were sought. Thus, a random sample of manual handling jobs would likely indicate even a lower percentage of exposures are amenable to analysis using the NIOSH equation than the percentages reported earlier. Thus, application of the equation will likely require violations to be made. The extent of the violations allowed will actually depend upon the expertise of the analyst, as an understanding of the effects of violating the restrictions can lead to valid interpretation of the results. This presents a situation where MMH models are perhaps only useful to experts with a comprehensive understanding of limitations and underlying assumptions (Buckle et al, 1992), despite the fact that many of the MMH assessment methods are developed for practitioners.

5.2. Task Design vs. Job Assessment

Perhaps the most relevant finding of the efforts to perform baseline evaluations of MMH jobs with the NIOSH equation is that the most significant problems occur when attempting to assess *jobs.* There are no historical data to prove or disprove the notion that the division of labor in manufacturing facilities may be retreating from the most acute levels in the past. However, anecdotal observations suggest that work organization factors like job rotation and flexible manufacturing have resulted in physical demands that are more complex from the standpoint of ergonomic assessment. On the other hand, the shifting economic rotation from manufacturing to service sectors in some economies may present similar problems. From the standpoint of task analysis, many service jobs are highly specialized, but have variable job demands when analyzed at the 'task' level. Delivery jobs provide a salient example, as the combinations of items delivered and the variable nature of the delivery locations (stairs, etc.) portray a complex ergonomic task analysis. The practical solution is often to analyze a subset of tasks. In each of these cases, the analyst is restricted to analyzing a subset of tasks comprising the job.

Subsets of tasks are often composed of the most stressful tasks, and may represent more of a peak exposure. For example, Waters et al. (1995) chose 10 lifting tasks in a grocery warehouse that were judged as having a high potential for injury, and representative of a diverse sample of stressful lifting postures. Many practitioners use similar approaches. The other approach is to use a representative sample. When analyzing warehouse jobs, Dempsey et al. (2000b) chose a similar approach to Waters et al. (1995), but attempted to select 15 tasks that were representative of the distribution of weights and vertical locations of the boxes handled.

A comprehensive assessment of a job represents more of a cumulative exposure, depending on how the tasks are aggregated during the analysis. A true estimate of cumulative exposure, for example daily exposure, may require a large number of samples, or an approach that utilizes integration of all tasks. Sampling on different days and even at different times throughout the year may be needed if seasonal variations exist. Of the possible aggregation approaches, integration and work sampling are methods capable of capturing the important determinants of exposure (magnitude, frequency and duration) (Dempsey 1999). Although the theory and practice of work sampling are well developed for traditional industrial engineering applications, the application to manual handling is not. Similarly, integration is often untenable due to the resources required. The study by Jäger et al. (2000) provides a salient example of the data reduction and analysis demands associated with integration of demands.

If the equation is being used in the *design* process, the relevance is diminished. For example, the relationships expressed by the multipliers can be used to suggest optimal fixed heights of conveyors, shelves, etc. The concepts presented by the individual multipliers can be used for training purposes as well. However, the above concepts have substantial relevance if the results are used to estimate the risk associated with a job. A risk assessment requires that the magnitude of the outcome of interest for a given exposure be estimated for the population of interest (National Research Council, 1983). In fact, the epidemiological study described earlier was motivated by the desire to enable this process for the NIOSH equation. Clearly, many problems exist when attempting comprehensive exposure assessments of *jobs* with the equation. At this time, there is not sufficient epidemiological data to confirm whether or not assessing peak loads is sufficient.

The problem becomes further complicated when the variety of potential outcomes is considered. The NIOSH equation and similar tools are designed primarily to prevent low-back pain (LBP) and the associated disability. When considering the difference between analyzing jobs (e.g., sampling approaches) vs. a subset of tasks, an important, yet often implicit, philosophical decision is made regarding the etiology of low-back disorders. In the case of peak exposures, it is implicitly assumed that the peak tasks may lead to episodes of LBP. In the case of more comprehensive job assessments, it is assumed that the cumulative exposure to the job may lead to episodes of LBP. Comprehensive job assessments may be more relevant to the prevention of low-back pain disability (LBPD). The relationship between a given level of LBP and disability is complex, but will likely vary across different levels of manual handling demands. Attention to peak demands may not be sufficient to prevent LBPD. In fact, it may possibly be a minimum manual handling demand that leads to the transition from pain to disability, i.e., the level of MMH demands that a worker with LBP can tolerate may be well below peak demands.

For the average user of techniques such as the NIOSH equation, it is implied that application will reduce the overall incidence of injuries and disorders associated with a particular workplace exposure (Buckle et al., 1992). Given the limitations analyzing some *jobs* with the equation, the valid use of the equation will be limited to design in some cases. This will reduce the potential for inaccurate risk characterizations of jobs being derived from a subset of task assessments.

5.3 What is the Task?

The NIOSH equation represents one technique for performing a task analysis of manual materials handling exposures involving lifting and lowering. In fact, the equation requires an implicit form of the task description for the exposure being analyzed: highly repetitive lifting and lowering tasks with parameters that do not change. Overall, these types of exposures appear to be less prevalent than when the equation was first published in 1981. Not only has automation reduced the number of such highly repetitive tasks, other organizational factors such as job rotation and other means of increasing job content has resulted in fewer jobs with small numbers of MMH tasks.

The case of very large numbers of tasks being performed, such as warehouse order pickers, represents a job that does not fit the task description required. The task may be considered assembling the orders, and it is impossible to precisely specify the parameters of individual lifting and lowering tasks within this broader task since the contents of orders are virtually stochastic. A different analysis approach developed to handle such exposures may be required. Techniques incorporating sampling schemes, such as OWAS (Karhu et al., 1977) or PATH (Buchholz et al., 1996), that are capable of analysing the broader order assembly 'task' are possibilities. For both techniques, work sampling is used to estimate the characteristics of the job demands to alleviate the need to continuously record data. Ideally, a task description should be developed first and an analysis technique suitable for the exposure should be selected. Although individual manual handling actions like lift, lower, push, pull, and carry, have traditionally been assumed to be the 'task,' many jobs are far too complex to comprehensively quantify using these terms.

5.4 Limitations

A limitation of this study is that jobs were selected using criteria, not at random. The selection criteria were oriented towards finding simpler jobs with the least within and between-day variation possible. Seasonal exposures were avoided, and the primary effect of this is that not construction jobs were studied. As mentioned earlier, some jobs in machine shops, flexible manufacturing cells, and similar settings were avoided. It is important to recognize that the results are not from a random selection. Finally, the jobs were all located in the U.S. Although there is no supporting literature, it is possible that there are geographical differences in manual handling. In spite of the limitations, the criteria were biased towards jobs amenable to analysis with the NIOSH equation.

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Appendix A

Data Collection Forms

JOB ROTATION WORKSHEET

Evaluated by (Name)	Office	Date	
Subject Name	Company Name	Location	SIC Code
Shift	Average Duration of Work Day (Hours)	Average Duration of Work Week (Days)	Restricted Duty (Y/N)

Rotation #	Job Title (and # if any)	Department Name (and # if any)	Rotation Schedule (Hours/Day or Hours/Week)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Customer Contact:

Name ____

Company ____

Title ____

Address ____

____

Phone # ____

Can Research Center call the customer contact directly to obtain OSHA logs? (Y/N) ________

JOB ROTATION DESCRIPTION

Rotation #	Job Title (and # if any)	Department Name (and # if any)	Description (Indicate (1) *most stressful job*, (2) *most frequent* or *second most stressful* job)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

JOB ROTATION SKETCH OF WORKPLACE

Company:____________________ Job Title:________________________ Subject Initials:__________

JOB ROTATION TIME SCHEDULE

Company:________________________ Job Title:_____________________________________ Subject Initials:__________

Job Rotation #	TASK DESCRIPTION	Time (e.g. 9:00-12:00 p.m.)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Job Rotation - MOST stressful rotation- Task Measurement Sheet

Company:__________________ Subject Initials:_________ Job Rotation Title (Rotation #):____________________________________

Department (#).:______________________________

Task Components	Measurements and Observations (Use Material Handling Scale Kit If Needed)																
TYPE Lift Lower Push Pull Carry Hold	**Task Group (All)** Letter	**Object Weight (Lift, Lower, Carry, Hold)** LB.	**Hand Height (All)** Start IN.	End IN.	**Hand Distance Away From Body (lift, lower)** Start IN.	End IN.	**Significant Control (lift, lower)** Y/N	**Duration (lift, lower)** S/M/L	**Coupling (lift, lower)** G/F/P	**Twisting (lift, lower)** Start DEG.	End DEG.	**Task Frequency (All)** Per Minute	**Pushing and Pulling Forces** Initial LB.	Sustained LB.	**Push Pull or Carrying Distance** FT.	**Cycle Time** MIN.
1)																	
2)																	
3)																	
4)																	
5)																	
6)																	
7)																	
8)																	
9)																	
10)																	
11)																	
12)																	
13)																	
14)																	

Job Rotation - MOST OFTEN or SECOND most stressful rotation- Task Measurement Sheet

Company:________________ Subject Initials:_________ Job Rotation Title (Rotation #):________________________________
Department (#).:____________________________

Task Components	Measurements and Observations (Use Material Handling Scale Kit If Needed)																
TYPE Lift Lower Push Pull Carry Hold	**Task Group (All)** Letter	**Object Weight (Lift, Lower, Carry, Hold)** LB.	**Hand Height (All)** Start IN.	End IN.	**Hand Distance Away From Body (lift, lower)** Start IN.	End IN.	**Significant Control (lift, lower)** Y/N	**Duration (lift, lower)** S/M/L	**Coupling (lift, lower)** G/F/P	**Twisting (lift, lower)** Start DEG.	End DEG.	**Task Frequency (All)** Per Minute	**Pushing and Pulling Forces** Initial LB.	Sustained LB.	**Push Pull or Carrying Distance** FT.	**Cycle Time** MIN.
1)																
2)																
3)																
4)																
5)																
6)																
7)																
8)																
9)																
10)																
11)																
12)																
13)																
14)																

Liberty Mutual Research Center for Safety and Health
Texas Tech University

Field Evaluation of MMH Criteria

Worker Survey

NAME ____

SOCIAL SECURITY NUMBER ___________________________

Date of Interview ______/______/______
Month Day Year

Background Information

1. Height ft__________in________

2. Weight______________

3. Gender: Male _____ Female ____

4. What is your date of birth? ______/______/______
Mo. Day Yr.

5. When did you **first** start working for this employer, either permanently or temporarily?

_________/_________
Month Year

6. What is your job title, or occupation?

____

5. When did you first start working **on this job**?

_________/_________
Month Year

7. How many hours per day, on average, do you do this job? Hours _______

8. How many days per week, on average, do you do this job? Days _______

9. What is the total percent of your day normally spent doing the following activities?

Lifting ______

Lowering ______

Pushing ______

Pulling ______

Holding ______

Carrying ______

10. How much time, **per day**, on average, are you in a vehicle commuting **to and from** work?

______Hours ______Minutes

11. Have you filed a workers' compensation claim **during the last 12 months** because of back pain?

Yes_____ No___________

12. Do you exercise regularly (on average 3 or more times per week) outside of work?

Yes ___________ No __________

13. IF YES, EXERCISE REGULARLY: What type of exercise do you do? Check **all** that apply.

Weight Lifting __________________
Running/Jogging __________________
Aerobics __________________
Golf __________________
Any Team Sport (including bowling, softball, etc.) __________________
Other (specify) __________________
____

14. Do you currently smoke cigarettes? Yes _____ No ______

15. IF YES, SMOKE: On average how many cigarettes a day do you smoke ? ______

16. IF YES, SMOKE: For how many years have you smoked? ______

17. Do you ever wear a back belt (support or brace) while doing this job?

Yes________ No__________

18. IF YES, HAVE WORN BACK BELT: When did you **first** start wearing it?

____________ ____________
Month Year

19. IF YES, HAVE WORN BACK BELT: How often do you wear your back belt? (read choices)

Always or most of the time ________

Sometimes or about half of the time ________

Very little or not at all ________

Only when handling heavy loads ________

20. IF YES, HAVE WORN BACK BELT: What type of belt do/did you wear?

Stretchable:

some types of nylon, any material that stretches when pulled ________

Non-Stretchable:

for example, belts made of webbed nylon, leather, or other non-elastic materials ________

We would like to send you a very short questionnaire (it will take 5 minutes or less) every 3 months for about a year and a half to ask about your job and about whether or not you have been injured at work. Also, we may want to call you once or twice during this period.

What is your home phone number? (________)________
area code

What is your home address?________________
Street Address or PO Box

____
City State Zip Code

Sometimes it is difficult to locate participants if they move or change phone numbers. To help us with this we ask for the name and address of two people who should know how to contact you in such instances (such as a family member). In case we can't reach you for some reason to ask about where you're working, may we have the name, address and phone number of a close relative or friend we can contact? **We'll only use this if we can not reach you by mail or phone.**

Name: ________________

Address: ________________
Street Address or PO Box

____
City State Zip Code

LIBERTY MUTUAL

The Research Center for Safety and Health
71 Frankland Road
Hopkinton, MA 01748
(508) 435-9061

Liberty Mutual Research Center for Safety and Health
Informed Consent Form

Purpose of Study

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Benefits

You will receive no direct benefit from your participation in this study but the information gained may result in the improved health of workers who perform manual handling tasks.

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Since you will be doing your regular job, there will not be any risks beyond those you encounter under normal working conditions.

Participation

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____________________ ____________________

Signature *Date*

____________________ ____________________

Witness *Date*

VARIABLE WEIGHT JOB WORKSHEET

Evaluated by (Name)	Office	Date

Company Name	Location	SIC Code

Subject Name	Job Title (and number if any)	Department Name (and number if any)

Shift	Average Duration of Work Day (hours)	Average Duration of Work Week (Days)	Restricted Duty (Y/N)

Job Description

Customer Contact:

Name ______________________________

Company ______________________________

Title ______________________________

Address ______________________________

____

Phone # ______________________________

Can Research Center call the customer contact directly to obtain OSHA logs? (Y/N) ________

VARIABLE WEIGHT SKETCH OF WORKPLACE

Company:____________________ Job Title:_________________________ Subject Initials:________

VARIABLE WEIGHT TIME SCHEDULE

Company:________________________ Job Title:_____________________________________ Subject Initials:__________

Task Numbers (From Pages 4 and 5)	DESCRIPTION	Time (e.g. 9:00-12:00 p.m.)

VARIABLE WEIGHT - Task Measurement Sheet 1

Company:______________________ Job Title:___________________________________ Subject Initials:_________

For tasks with variable weight, enter a "V" in the Object Weight field.

Task Components	Measurements and Observations (Use Material Handling Scale Kit If Needed)																
TYPE Lift Lower Push Pull Carry Hold	**Task Group (All)**	**Object Weight (Lift, Lower, Carry, Hold)**	**Hand Height (All)**		**Hand Distance Away From Body (lift, lower)**		**Significant Control (lift, lower)**	**Duration (lift, lower)**	**Coupling (lift, lower)**	**Twisting (lift, lower)**		**Task Frequency (All)**	**Pushing and Pulling Forces**		**Push Pull or Carry Distance**	**Cycle Time**
	Letter	LB.	Start IN.	End IN.	Start IN.	End IN.	Y/N	S/M/L	G/F/P	Start DEG.	End DEG.	Per Minute	Initial LB.	Sustained LB.	FT.	MIN.
1)																
2)																
3)																
4)																
5)																
6)																
7)																
8)																
9)																
10)																
11)																
12)																
13)																
14)																

VARIABLE WEIGHT - Task Measurement Sheet 2

Company:________________________ Job Title:_____________________________________ Subject Initials:__________

For tasks with variable weight, enter a "V" in the Object Weight field.

Task Components	Measurements and Observations (Use Material Handling Scale Kit If Needed)															
TYPE Lift Lower Push Pull Carry Hold	**Task Group (All)**	**Object Weight (Lift, Lower, Carry, Hold)**	**Hand Height (All)**		**Hand Distance Away From Body (lift, lower)**		**Significant Control (lift, lower)**	**Duration (lift, lower)**	**Coupling (lift, lower)**	**Twisting (lift, lower)**		**Task Frequency (All)**	**Pushing and Pulling Forces**		**Push Pull or Carry Distance**	**Cycle Time**
	Letter	LB.	Start IN.	End IN.	Start IN.	End IN.	Y/N	S/M/L	G/F/P	Start DEG.	End DEG.	Per Minute	Initial LB.	Sustained LB.	FT.	MIN.
15)																
16)																
17)																
18)																
19)																
20)																
21)																
22)																
23)																
24)																
25)																
26)																
27)																
28)																

VARIABLE WEIGHT WORKSHEET

Company:______________________ Job Title:___________________________________ Subject Initials:_________

Measurements and Observations (Use Objective Data or Estimates from the Workers)										
Variable Weight Task # (From Pages 4 and 5)	**Average Object Weight** LB.	**Maximum Object Weight** LB.	Percentage of Loads in the Following Categories							**Objective Data?** Yes/No
			0 to 20 LB. %	**21 to 40 LB.** %	**41 to 60 LB.** %	**61 to 80 LB.** %	**81 to 100 LB.** %	**Over 100 LB.** %	**TOTAL** %	
									100	
									100	
									100	
									100	
									100	
									100	
									100	
									100	
									100	
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									100	
									100	
									100	
									100	

V7

									100	

Liberty Mutual Research Center for Safety and Health
Texas Tech University

Field Evaluation of MMH Criteria

Worker Survey

NAME ____

SOCIAL SECURITY NUMBER ___________________________

Date of Interview ______/______/______
Month Day Year

Background Information

1. Height ft__________in________

2. Weight_______________

3. Gender: Male _____ Female ____

4. What is your date of birth? ______/______/______
Mo. Day Yr.

5. When did you **first** start working for this employer, either permanently or temporarily?

_________/_________
Month Year

6. What is your job title, or occupation?

____

5. When did you first start working **on this job**?

_________/_________
Month Year

7. How many hours per day, on average, do you do this job? Hours _______

8. How many days per week, on average, do you do this job? Days ________

9. What is the total percent of your day normally spent doing the following activities?

Lifting ______

Lowering ______

Pushing ______

Pulling ______

Holding ______

Carrying ______

10. How much time, **per day**, on average, are you in a vehicle commuting **to and from** work?

______Hours ______Minutes

11. Have you filed a workers' compensation claim **during the last 12 months** because of back pain?

Yes_____ No__________

12. Do you exercise regularly (on average 3 or more times per week) outside of work?

Yes __________ No __________

13. IF YES, EXERCISE REGULARLY: What type of exercise do you do? Check **all** that apply.

Weight Lifting ______________
Running/Jogging ______________
Aerobics ______________
Golf ______________
Any Team Sport (including bowling, softball, etc.) ______________
Other (specify) ______________

____

14. Do you currently smoke cigarettes? Yes _____ No ______

15. IF YES, SMOKE: On average how many cigarettes a day do you smoke ? ______

16. IF YES, SMOKE: For how many years have you smoked? ______

17. Do you ever wear a back belt (support or brace) while doing this job?

Yes________ No__________

18. IF YES, HAVE WORN BACK BELT: When did you **first** start wearing it?

__________ Month __________ Year

19. IF YES, HAVE WORN BACK BELT: How often do you wear your back belt? (read choices)

Always or most of the time ________

Sometimes or about half of the time ________

Very little or not at all ________

Only when handling heavy loads ________

20. IF YES, HAVE WORN BACK BELT: What type of belt do/did you wear?

Stretchable:

some types of nylon, any material that stretches when pulled ______

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What is your home address?______________________________________
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City State Zip Code

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_______________________	_______________________
Signature	*Date*
_______________________	_______________________
Witness	*Date*

Liberty Mutual Research Center for Safety and Health
Texas Tech University

Field Evaluation of MMH Criteria

Worker Survey

NAME ____

SOCIAL SECURITY NUMBER ____________________________

Date of Interview ______/______/______
Month Day Year

Background Information

1. Height ft________in________

2. Weight____________

3. Gender: Male ______ Female _____

4. What is your date of birth? ______/______/______
Mo. Day Yr.

5. When did you **first** start working for this employer, either permanently or temporarily?

________/________
Month Year

6. What is your job title, or occupation?

____

5. When did you first start working **on this job**?

________/________
Month Year

7. How many hours per day, on average, do you do this job? Hours __________

8. How many days per week, on average, do you do this job? Days ______

9. What is the total percent of your day normally spent doing the following activities?

Lifting _____

Lowering _____

Pushing _____

Pulling _____

Holding _____

Carrying _____

10. How much time, **per day**, on average, are you in a vehicle commuting **to and from** work?

_____Hours _____Minutes

11. Have you filed a workers' compensation claim **during the last 12 months** because of back pain?

Yes_________ No_________

12. Do you exercise regularly (on average 3 or more times per week) outside of work?

Yes _________ No _________

13. IF YES, EXERCISE REGULARLY: What type of exercise do you do? Check **all** that apply.

Weight Lifting _______________
Running/Jogging _______________
Aerobics _______________
Golf _______________
Any Team Sport (including bowling, softball, etc.) _______________
Other (specify) _______________

____

14. Do you currently smoke cigarettes? Yes _____ No _____

15. IF YES, SMOKE: On average how many cigarettes a day do you smoke ? _____

16. IF YES, SMOKE: For how many years have you smoked? _____

17. Do you ever wear a back belt (support or brace) while doing this job?

Yes__________ No_________

18. IF YES, HAVE WORN BACK BELT: When did you **first** start wearing it?

__________ __________
Month Year

19. IF YES, HAVE WORN BACK BELT: How often do you wear your back belt? (read choices)

Always or most of the time ________
Sometimes or about half of the time ________
Very little or not at all ________
Only when handling heavy loads ________

20. IF YES, HAVE WORN BACK BELT: What type of belt do/did you wear?

Stretchable:
some types of nylon, any material that stretches when pulled ______

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What is your home address?______________________________
Street Address or PO Box

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City State Zip Code

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Name: ______________________________________

Address: ____________________________________
Street Address or PO Box

____
City State Zip Code

STANDARD JOB WORKSHEET

Evaluated by (Name)	Office	Date

Company Name	Location	SIC Code

Subject Name	Job Title (and number if any)	Department Name (and number if any)

Shift	Average Duration of Work Day (hours)	Average Duration of Work Week (Days)	Restricted Duty (Y/N)

Job Description

Customer Contact:

Name ______________________________

Company ______________________________

Title ______________________________

Address ______________________________

____

Phone # ______________________________

Can Research Center call the customer contact directly to obtain OSHA logs? (Y/N) ________

STANDARD JOB SKETCH OF WORKPLACE

Company:____________________ Job Title:________________________ Subject Initials:________

STANDARD JOB TIME SCHEDULE

Company:________________________ Job Title:_____________________________________ Subject Initials:__________

Task Numbers (From Pages 4 and 5)	DESCRIPTION	Time (e.g. 9:00-12:00 p.m.)

STANDARD JOB - Task Measurement Sheet 1

Company:____________________ Job Title:________________________________ Subject Initials:_________

Task Components	Measurements and Observations (Use Material Handling Scale Kit If Needed)																
TYPE Lift Lower Push Pull Carry Hold	**Task Group (All)**	**Object Weight (Lift, Lower, Carry, Hold)**	**Hand Height (All)**		**Hand Distance Away From Body (lift, lower)**		**Significant Control (lift, lower)**	**Duration (lift, lower)**	**Coupling (lift, lower)**	**Twisting (lift, lower)**		**Task Frequency (All)**	**Pushing and Pulling Forces**		**Push Pull or Carrying Distance**	**Cycle Time**
	Letter	LB.	Start IN.	End IN.	Start IN.	End IN.	Y/N	S/M/L	G/F/P	Start DEG.	End DEG.	Per Minute	Initial LB.	Sustained LB.	FT.	MIN.
1)																
2) .																
3)																
4)																
5)																
6)																
7)																
8)																
9)																
10)																
11)																
12)																
13)																
14)																

STANDARD JOB - Task Measurement Sheet 2

Company:______________________ Job Title:__________________________________ Subject Initials:_________

Task Components	Measurements and Observations (Use Material Handling Scale Kit If Needed)																
TYPE Lift Lower Push Pull Carry Hold	**Task Group (All)**	**Object Weight (Lift, Lower, Carry, Hold)**	**Hand Height (All)**		**Hand Distance Away From Body (lift, lower)**		**Significant Control (lift, lower)**	**Duration (lift, lower)**	**Coupling (lift, lower)**	**Twisting (lift, lower)**		**Task Frequency (All)**	**Pushing and Pulling Forces**		**Push Pull or Carry Distance**	**Cycle Time**
	Letter	LB.	Start IN.	End IN.	Start IN.	End IN.	Y/N	S/M/L	G/F/P	Start DEG.	End DEG.	Per Minute	Initial LB.	Sustained LB.	FT.	MIN.
15)																
16)																
17)																
18)																
19)																
20)																
21)																
22)																
23)																
24)																
25)																
26)																
27)																
28)																

Liberty Mutual Research Center for Safety and Health
Texas Tech University

Field Evaluation of MMH Criteria

Worker Survey

NAME ____

SOCIAL SECURITY NUMBER ___________________________

Date of Interview ______/______/______
Month Day Year

Background Information

1. Height ft__________in________

2. Weight_______________

3. Gender: Male _____ Female ____

4. What is your date of birth? ______/______/______
Mo. Day Yr.

5. When did you **first** start working for this employer, either permanently or temporarily?

______/______
Month Year

6. What is your job title, or occupation?

____

5. When did you first start working **on this job**?

______/______
Month Year

7. How many hours per day, on average, do you do this job? Hours _______

8. How many days per week, on average, do you do this job? Days _______

9. What is the total percent of your day normally spent doing the following activities?

Lifting ______

Lowering ______

Pushing ______

Pulling ______

Holding ______

Carrying ______

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Street Address or PO Box

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City State Zip Code

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_______________________________ _______________________
Signature *Date*

_______________________________ _______________________
Witness *Date*

WAREHOUSING/COMPLEX JOB WORKSHEET

Evaluated by (Name)	Office	Date

Company Name	Location	SIC Code

Subject Name	Job Title (and number if any)	Department Name (and number if any)

Shift	Average Duration of Work Day (hours)	Average Duration of Work Week (Days)	Restricted Duty (Y/N)

Job Description

Customer Contact:

Name ____

Company ____

Title ____

Address ____

____

Phone # ____

Can Research Center call the customer contact directly to obtain OSHA logs? (Y/N) _________

WAREHOUSING/COMPLEX JOB SKETCH OF WORKPLACE

Company:____________________ Job Title:________________________ Subject Initials:________

WAREHOUSING/COMPLEX JOB TIME SCHEDULE

Company:______________________ Job Title:__________________________________ Subject Initials:_________

JOB ACTIVITY (e.g. Order Picking; Paper work)	DECRIPTION OF ACTIVITY	Time (e.g. 9:00-12:00 p.m)

WAREHOUSING/COMPLEX JOB- Task Measurement Sheet 1

Company:____________________ Job Title:________________________________ Subject Initials:_________

	Measurements and Observations (Use Material Handling Scale Kit If Needed)										
Pick/Object Number	**TYPE** Lift/Lower	**Object Weight**	**Hand Height** START	END	**Hand Distance** START	END	**Sig. Control** Y/N	**Coupling** G/F/P	**Twisting (DEG)** START	END	**Carrying Dist.** FT.
1a. Initial. Location (e.g. Pick Slot)		lb	in	in	in	in			deg	deg	
1b. Final Location (e.g. Pallet)											
2a. Initial. Location											
2b. Final Location											
3a. Initial. Location											
3b. Final Location											
4a. Initial. Location											
4b. Final Location											
5a. Initial. Location											
5b. Final Location											
6a. Initial. Location											
6b. Final Location											
7a. Initial. Location											
7b. Final Location											
8a. Initial. Location											
8b. Final Location											
9a. Initial. Location											
9b. Final Location											
10a. Initial. Location											
10b. Final Location											

WAREHOUSING/COMPLEX JOB- Task Measurement Sheet 2

Company:____________________ Job Title:______________________________ Subject Initials:_________

	Measurements and Observations (Use Material Handling Scale Kit If Needed)											
Pick/Object Number	**TYPE** Lift/Lower	**Object Weight**	**Hand Height** START	END	**Hand Distance** START	END	**Sig. Control** Y/N	**Coupling** G/F/P	**Twisting (DEG)** START	END	**Carrying Dist.** FT.
11a. Initial. Location (e.g. Pick Slot)		lb	in	in	in	in			deg	deg	
11b. Final Location (e.g. Pallet)											
12a. Initial. Location											
12b. Final Location											
13a. Initial. Location											
13b. Final Location											
14a. Initial. Location											
14b. Final Location											
15a. Initial. Location											
15b. Final Location											

SPECIAL WAREHOUSE FREQUENCY CALCULATION (Picks Per Minute):

Number of Picks Observed in 15 Minute Observation Period:__________

AND (If Available)

Calculated Rate Based on Daily Picking Info:________________
Source of Information (e.g., work standards, historical average, etc.):__________

OTHER MMH TASKS:

Measure other (up to FIVE) major MMH tasks that the workers perform besides the typical task measured above (order picking).

TYPE Lift Lower Push Pull Carry Hold	Object Weight (Lift, Lower, Carry, Hold) LB.	Hand Height Start IN.	 End IN.	Hand Distance Away From Body (lift, lower) Start IN.	 End IN.	Significant Control (lift, lower) Y/N	Duration (lift, lower) S/M/L	Coupling (lift, lower) G/F/P	Twisting (lift, lower) Start DEG.	 End DEG.	Task Frequency Per Minute	Pushing and Pulling Forces Initial LB.	 Sustained LB.	Push Pull or Carrying Distance FT.
1														
2														
3														
4														
5														

MOST STRESSFUL TASK:

Task (e.g. Picking Bags of Dog Food):____

Was it Measured Above? Y/N_______ If NO, Measure the appropriate task Information below:

TYPE Lift Lower Push Pull Carry Hold	Object Weight (Lift, Lower, Carry, Hold) LB.	Hand Height Start IN.	 End IN.	Hand Distance Away From Body (lift, lower) Start IN.	 End IN.	Significant Control (lift, lower) Y/N	Duration (lift, lower) S/M/L	Coupling (lift, lower) G/F/P	Twisting (lift, lower) Start DEG.	 End DEG.	Task Frequency Per Minute	Pushing and Pulling Forces Initial LB.	 Sustained LB.	Push Pull or Carrying Distance FT.

Liberty Mutual Research Center for Safety and Health
Texas Tech University

Field Evaluation of MMH Criteria

Worker Survey

NAME ______________________________

SOCIAL SECURITY NUMBER ____________________

Date of Interview ____/____/____
Month Day Year

Background Information

1. Height ft________in________

2. Weight____________

3. Gender: Male _____ Female ____

4. What is your date of birth? ____/____/____
Mo. Day Yr.

5. When did you **first** start working for this employer, either permanently or temporarily?

____/____
Month Year

6. What is your job title, or occupation?

____

5. When did you first start working **on this job**?

____/____
Month Year

7. How many hours per day, on average, do you do this job? Hours ______

8. How many days per week, on average, do you do this job? Days ______

9. What is the total percent of your day normally spent doing the following activities?

Lifting ______

Lowering ______

Pushing ______

Pulling ______

Holding ______

Carrying ______

10. How much time, **per day**, on average, are you in a vehicle commuting **to and from** work?

______Hours ______Minutes

11. Have you filed a workers' compensation claim **during the last 12 months** because of back pain?

Yes_____ No___________

12. Do you exercise regularly (on average 3 or more times per week) outside of work?

Yes ___________ No __________

13. IF YES, EXERCISE REGULARLY: What type of exercise do you do? Check **all** that apply.

Weight Lifting	____________
Running/Jogging	____________
Aerobics	____________
Golf	____________
Any Team Sport (including bowling, softball, etc.)	____________
Other (specify)	____________

____

14. Do you currently smoke cigarettes? Yes _____ No _____

15. IF YES, SMOKE: On average how many cigarettes a day do you smoke ? ______

16. IF YES, SMOKE: For how many years have you smoked? ______

17. Do you ever wear a back belt (support or brace) while doing this job?

Yes________ No__________

18. IF YES, HAVE WORN BACK BELT: When did you **first** start wearing it?

__________ Month __________ Year

19. IF YES, HAVE WORN BACK BELT: How often do you wear your back belt? (read choices)

Always or most of the time ___________

Sometimes or about half of the time ___________

Very little or not at all ___________

Only when handling heavy loads ___________

20. IF YES, HAVE WORN BACK BELT: What type of belt do/did you wear?

Stretchable:

some types of nylon, any material that stretches when pulled ________

Non-Stretchable:

for example, belts made of webbed nylon, leather, or other non-elastic materials ________

We would like to send you a very short questionnaire (it will take 5 minutes or less) every 3 months for about a year and a half to ask about your job and about whether or not you have been injured at work. Also, we may want to call you once or twice during this period.

What is your home phone number? (__________________)__________________
area code

What is your home address?____
Street Address or PO Box

____
City State Zip Code

Sometimes it is difficult to locate participants if they move or change phone numbers. To help us with this we ask for the name and address of two people who should know how to contact you in such instances (such as a family member). In case we can't reach you for some reason to ask about where you're working, may we have the name, address and phone number of a close relative or friend we can contact? **We'll only use this if we can not reach you by mail or phone.**

Name: ____

Address: ____
Street Address or PO Box

____
City State Zip Code

LIBERTY MUTUAL.

The Research Center for Safety and Health
71 Frankland Road
Hopkinton, MA 01748
(508) 435-9061

Liberty Mutual Research Center for Safety and Health
Informed Consent Form

Purpose of Study

The purpose of this study is to evaluate and describe tasks and workplaces where materials are handled manually. Workers performing the manual tasks will be interviewed. The primary goal of the study is to determine the relationships between job demands and future occurrences of injury. Eventually, the results of the study will be used to (re)design workplaces to minimize the probability of being injured.

Benefits

You will receive no direct benefit from your participation in this study but the information gained may result in the improved health of workers who perform manual handling tasks.

Risks

Since you will be doing your regular job, there will not be any risks beyond those you encounter under normal working conditions.

Participation

Your participation in this study is strictly voluntary. You are free to decline to participate in the study without penalty or question. You are also free to decline to answer any questions. You will be under no pressure to continue. If you agree to participate you will be interviewed, observed doing your job, and measurements will be taken of a variety of your work tasks. General health and employment information will also be collected. We would like to send you a very short questionnaire (takes less than 5 minutes to fill out) every 3 months during the next 1 1/2 years to ask whether or not you are working in the same job and to ask about any recent injuries at work. Also, if you are willing, we may wish to call you once or twice during the 1 1/2 year period to ask you more details about your responses to the questions.

Videotaping

In this study, you may be videotaped as you perform your job for research purposes only.

____________ Initials

LIBERTY MUTUAL.

The Research Center for Safety and Health
71 Frankland Road
Hopkinton, MA 01748
(508) 435-9061

Confidentiality

Our policy is to consider test data to be privileged. All data collected will be identified by a subject number and not your name. Individual personal data gathered through the questions will not be shared with your employer or anyone else. The questionnaire data collected are strictly for research purposes. Any published work will not refer to you by name, rather the results will be presented in a manner that summarizes or averages the data.

Supervision

This study will be directly supervised by Patrick Dempsey, Ph.D. Questions or comments about participation should be directed to Dr. Dempsey at (508) 435-9061 (x309). If, after contacting the above person, you do not feel that your concerns were adequately addressed, you may contact Mr. Jim Klock, Director of Operations for the Research Center at (508) 435-9061 (x303).

Consent

Please read the following statement and sign on the line below if you agree to participate in the study.

I have read this document or it has been read to me and understand the purpose of the study, and what is expected of me if I agree to participate. By signing this consent form, I agree freely to participate in this study without any pressure having been placed on me to do so.

______________________ ______________________
Signature *Date*

______________________ ______________________
Witness *Date*

Appendix B

Data Collection Instructions

FIELD EVALUATION OF MANUAL MATERIALS HANDLING CRITERIA

DATA COLLECTION INSTRUCTIONS
DATA COLLECTION FORMS

VERSION 2.1 - MARCH 22, 1999

LIBERTY MUTUAL

RESEARCH CENTER FOR SAFETY & HEALTH
HOPKINTON, MASSACHUSETTS

TEXAS TECH UNIVERSITY
INSTITUTE FOR ERGONOMICS RESEARCH
LUBBOCK, TEXAS

CHECKLIST

CUSTOMER COOPERATION

- ❑ Information pamphlets

MATERIALS TO BRING

- ❑ MMH Kit with Protractor
- ❑ Video cameras and tape (if available)
- ❑ Data Collection Instructions
- ❑ Data Collection Forms
- ❑ Copies of letter/consent form for subjects

JOB SELECTION

- ❑ No patient handling
- ❑ No vehicle drivers
- ❑ No Jobs involving substantial seasonal work

DATA COLLECTION

- ❑ Consent forms
- ❑ Questionnaires
- ❑ Job Worksheet Packets
  - Standard Job Packet
  - Warehousing/Complex Job Packet,
  - Job Rotation Packet,
  - Variable Weight Packet
- ❑ OSHA 200 Logs for past year (or 3 years if available)

Project Management Contacts

Principal Investigator

Patrick G. Dempsey, Ph.D.
Liberty Mutual Research Center for Safety and Health
71 Frankland Road
Hopkinton, MA 01748
Phone: (508) 435-9061 X309
SDN: 8-446-2309
FAX: (508) 435-8136
E-mail: patrick.dempsey@libertymutual.com

Questions concerning data collection procedures or the study in general should be directed to Patrick.

Product Manager of Ergonomics and Manufacturing Technology

Wayne Maynard
Liberty Mutual Group
175 Berkeley Street
Boston, MA 02117
Phone: (617) 357-9500 X42676
SDN: 8-444-2676
FAX: (617) 357-5349
E-mail: wayne.maynard@libertymutual.com

Questions concerning administrative details and other related questions should be directed to Wayne.

Incentives

• As incentives for participating in this study, participating locations can select ONE of the following:

- One (1) free copy of CompuTask™ with single user license
- Two (2) free Summit Training video rentals
- Any one (1) "5-Minute Safety Video" of their choice

1.0 SELECTING LOCATIONS, TASKS AND SUBJECTS

1.1 Location Selection

One of the first steps involved in the study will be selecting locations to participate. Please use the following guidelines as a starting point in this process:

a. Select locations with whom you have good working relationships.

b. Select locations with stable jobs (no seasonal schedules or job rotation periods of more than one week).

c. Select locations with sufficient MMH jobs.

1.2 Job Selection

A critical step in the process of collecting the data is selecting those jobs that will be analyzed.

The following EXCLUSION criteria must be adhered to when selecting jobs for the study:

a. Jobs where workers perform patient handling.

b. Jobs which involve substantial vehicle driving.

c. Jobs involving seasonal work.

The following INCLUSION criteria should be used when selecting jobs for the study:

a. Jobs with few component tasks, i.e., try to select jobs that have fewer distinct MMH tasks.

b. Select jobs with the least day-to-day variation. We have to assume the data collected are a reasonable representation of what the worker does every day.

c. Jobs with multiple workers are useful as they will save you time if you select several workers.

d. Include a variety of job types with respect to the MMH demands, not just very stressful jobs.

1.3 Subject Selection

Subjects will be selected from the jobs that qualify for the study. Please use the following criteria to select subjects:

a. Subjects must be full-time employees.

b. Subjects must have 1 week of experience.

c. Select male **and** female subjects.

d. Subjects must be willing to participate.

1.3a Gathering Subject Data

In addition to job, task, and workplace data, data on the individual subjects selected for participation will be required. To collect these data, you will need to interview the subjects. These data are as important as the other data. Subjects will also have to fill out a consent form. If subjects are uncomfortable about answering certain questions, they do not have to answer them. However, if subjects do not answer a question, please do not leave the space in the questionnaire blank. Indicate that the subject chose not to answer by putting the letters 'RA' (Refused to Answer) in the space provided.

1.4 Types of Jobs to be Studied:

This section briefly discusses each of the major classes of jobs that will be included in the study. The specific details of how to collect data for each of these job types will be discussed in more detail later.

Standard Jobs refers to jobs in which the manual handling tasks that are performed from day to day are identical or very similar. Examples include assembly tasks involving lifting or lowering during each cycle, palletizing tasks of the same or similar products, etc. In general, these jobs involve MMH tasks that stay the same (i.e., weight, hand height, etc., for each task are quite stable).

Variable Weight Jobs refers to those jobs in which the MMH tasks performed remain relatively stable, but the weight changes. For example, a worker in a machine shop may operate a certain type of metal removing machine (such as a lathe or mill) approximately once every 5 minutes. The process may require the worker to lift the stock into the machine and out of the machine, but the weight of the workpiece varies depending upon the product. In this case, the task parameters are measured, but detailed information on the weight distribution will need to be collected.

Warehousing/Complex Jobs are acceptable for the study even though they involve many different types of lifts/lowers and different loads. The way to collect data in these situations is to use a sampling strategy. Other than exclusively warehouse picking jobs, there are situations in which a very large number of distinct MMH tasks are performed (complex jobs). These complex jobs will be analyzed in the same manner as warehousing jobs. An example of a "complex" job would be unloading trucks (assuming the same worker is not the driver, since significant driving excludes a job).

Job Rotation is acceptable for the study as long as the rotation schedule is regular and on a daily or weekly basis as compared to a monthly or seasonal basis. At least one of the jobs in a rotating schedule is required to have a significant MMH work component. However, some information on each of the rotations will be required.

2.0 GATHERING WORKPLACE INFORMATION

A critical aspect of performing data collection will be deciding on the appropriate job type and the corresponding packet of worksheets to complete. The flow chart in Figure 1 has been created to assist you in this process.

A great deal of care must be taken at the work site to identify and record relevant information for each type of job. Since the purpose of the study is ultimately to provide the customer with appropriate recommendations concerning the NIOSH equation and CompuTask®, accurate information must be gathered to draw valid conclusions. All jobs which fit the selection criteria will have *at minimum* the job description completed. In addition to this form, the appropriate Job Evaluation Worksheets should be used to record information on the task components or elements.

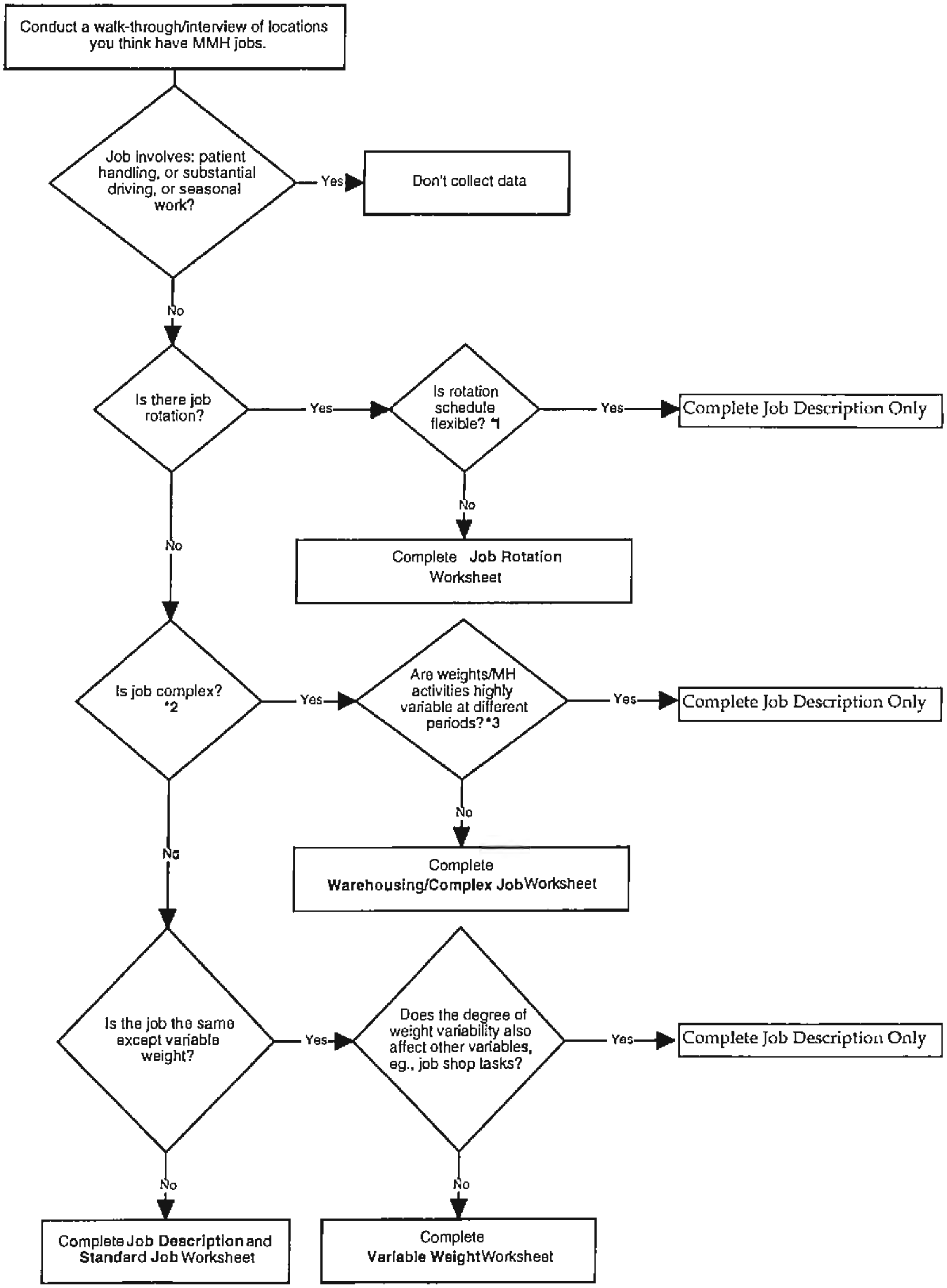
2.1 Choosing Appropriate Worksheets

There are four types of worksheets for each of the job types discussed in Section1.4. Figure 1 illustrates a broad overview of the first step in the data collection, which is selecting which worksheet to use. Some jobs involving manual handling will not be included in the study for the reasons mentioned.

2.1.a If Job Description Is The Only Information Recorded

If the Job Description is the only information recorded about the job, please provide a detailed explanation why. **It is critical that you provide as much information as is available since this information will be used to provide suggestions for future MMH guidelines. If it does not fit on the first page, please use an additional sheet.**

Figure 1. Data Collection Flow Chart



1. Flexible work cells where employees choose frequency or type of rotation.
2. In terms of variable Vertical/Horizontal distances, or weight, eg., warehouse picking.
3. Seasonal freight shipping/handling.

2.2 Completing Standard Job Worksheets

The four different types of Job Evaluation Worksheet Packets attached to the end of this document were developed for recording the elements of each of the manual materials handling tasks. A separate set of worksheets is provided for standard jobs, warehousing/complex jobs, job rotation, and variable weight jobs. The use of the forms is required to avoid omitting task elements essential for the study. The material handling evaluation kit and protractor must be used for taking the necessary measurements.

Whenever possible, the data collection procedures were designed to match the CompuTask® procedures. However, in some cases, "Different from CompuTask®" appears, indicating that the measurements need to be taken some other way. *Please use extra caution when measuring those variables with which you are not familiar.*

2.2.a First Page of Worksheet

Record your name, office and the date on which the data are collected on the first line. Following this are several cells concerning the work schedule, company information, etc. For restricted (light) duty, place a yes or no depending on whether or not a restricted duty policy is in place. For the job description, a brief clear, concise description of the job should include the department name, job title, operation, etc. If job rotation is involved, a description should be provided for each job that the worker performs (even if MMH is not involved). Additional sheets may have to be attached for this purpose.

The customer contact section should provide the name, address, and phone number of a person at the site for purposes of obtaining follow-up data as well as for informing locations about the progress of the study. Also, this person will be sent the executive summary of the results. For the purposes of obtaining future OSHA 200 logs, ask the contact if someone from the Research Center may contact him/her directly (Yes/No).

2.2.b Sketch of Workplace and Time Schedule

The Sketch of Workplace does not have to be completed, but is meant to serve as an aid for data collection.

The Time Schedule is very important, and must be completed for all four types of worksheet packets. There are two methods used for recording the time schedule. Choose one of the following methods according to the type of worksheet completed:

- *Standard Job or Variable Weight Worksheet-* A time schedule (e.g., 8:00 a.m. - 10:00 a.m.) along with a short description of each of the task components listed on pages 4 and 5 in these packets should be recorded.

- *Job Rotation or Warehousing/Complex Worksheet* - An overall time schedule (e.g., 8:00 a.m. - 10:00 a.m.) should be completed for each job rotation/major activity indicated on page 1 of these worksheet packets along with a short description of the major tasks included in each category.

2.2.c Task Measurement Sheets

For all four types of worksheets, there are task measurement sheets for entering the relevant job parameters so that the NIOSH Lifting Index can be calculated. The measurements for all types of worksheets are detailed in the remainder of Section 2. Specific instructions are also provided in Sections 3-5 for job rotation, warehousing/complex, and variable weight worksheets.

The Task Measurement Sheets should be completed as follows:

Task Components:

Enter the components in the sequence in which they occur in the task. A job can consist of a single component tasks or may have multiple component tasks. Care must be taken at this point.

- Single component task: In a single component task, only one component is performed at a time. For example, lifting for one hour followed by carrying for the next hour, and then lowering for a third hour should be analyzed as three single components.

- Multiple component tasks: A multiple component task occurs when two or more components are performed before handling another object. For example, a multiple component task having three components would be lifting an object, carrying the object, lowering the object and then returning for the next object.

- Stacking or Palletizing: The manual transfer of each item to or from each separate level of a stacking or palletizing operation must be considered and analyzed as a separate task.

*A task should be considered **unique** if:*

(1) The task type (push, pull, lift, lower, carry, hold) is different from all other tasks performed.

(2) Any of the variables required for a task type is different (e.g., the weight of the load is heavier or lighter, the box must be lifted 5 inches higher, etc.).

Task Grouping:

Please indicate task groupings by adding a common letter next to tasks that are performed simultaneously. For example, if a worker performs a lift, a push, a lower, and then repeats this sequence for 2 hours, these tasks are performed simultaneously. Put an A next to all these. On the other hand, if the worker lifts for 1 hr., followed by pushes for 1 hr., then the lift would be assigned an A and the pushes a B.

Standard/Job Rotation/Variable Weight Worksheets- If more than 5 task groupings involve MMH, then only five task groupings should be analyzed and reported on the form. Similar to selecting jobs, the analyst needs to select the 5 most stressful MMH task groupings completed by the operator in the job. Included in these five should be the task component that comprises the largest percentage (of time) of the work cycle. If the task that is done for the largest percentage of time is not among the 5 most stressful MMH tasks, then the 4 most stressful tasks should be analyzed in addition to the task done for the longest duration.

2.3 Lifting/lowering tasks:

2.3.a Object Weight (pounds)

If the weight of the object is not indicated on the object itself, it can be determined by weighing the object on a scale in the facility, or by using the spring scale in our kit. Enter the weight to the closest pound.

Variable Weight Worksheet- If the weight is variable for the task being analyzed, put a "V" in this column and fill out a line on the Variable Weight Data Sheet for this task. Refer to Section 3.0 for specific instructions regarding the variable weight worksheet.

2.3.b Hand Height (inches) (start and end of lift/lower)

Enter the average height of the two hands (using the middle knuckle as a reference point) above the floor at the start and at the end of the lift/lower. Enter the hand height to the closest inch.

2.3.c Horizontal Hand Distance (inches) (start and end of lift/lower):

THIS IS DIFFERENT FROM CompuTask®.

This measure is the distance from the mid-point of the hand grasps (the worker's large middle knuckle) projected down to the floor to the mid-point of the line joining the inner ankle bones during performance of the component and must be measured at the start and end of the lift/lower. If the two hands are kept at different distances, enter the average. This horizontal location measure is illustrated in Figure 2. Enter the hand distance to the closest inch.

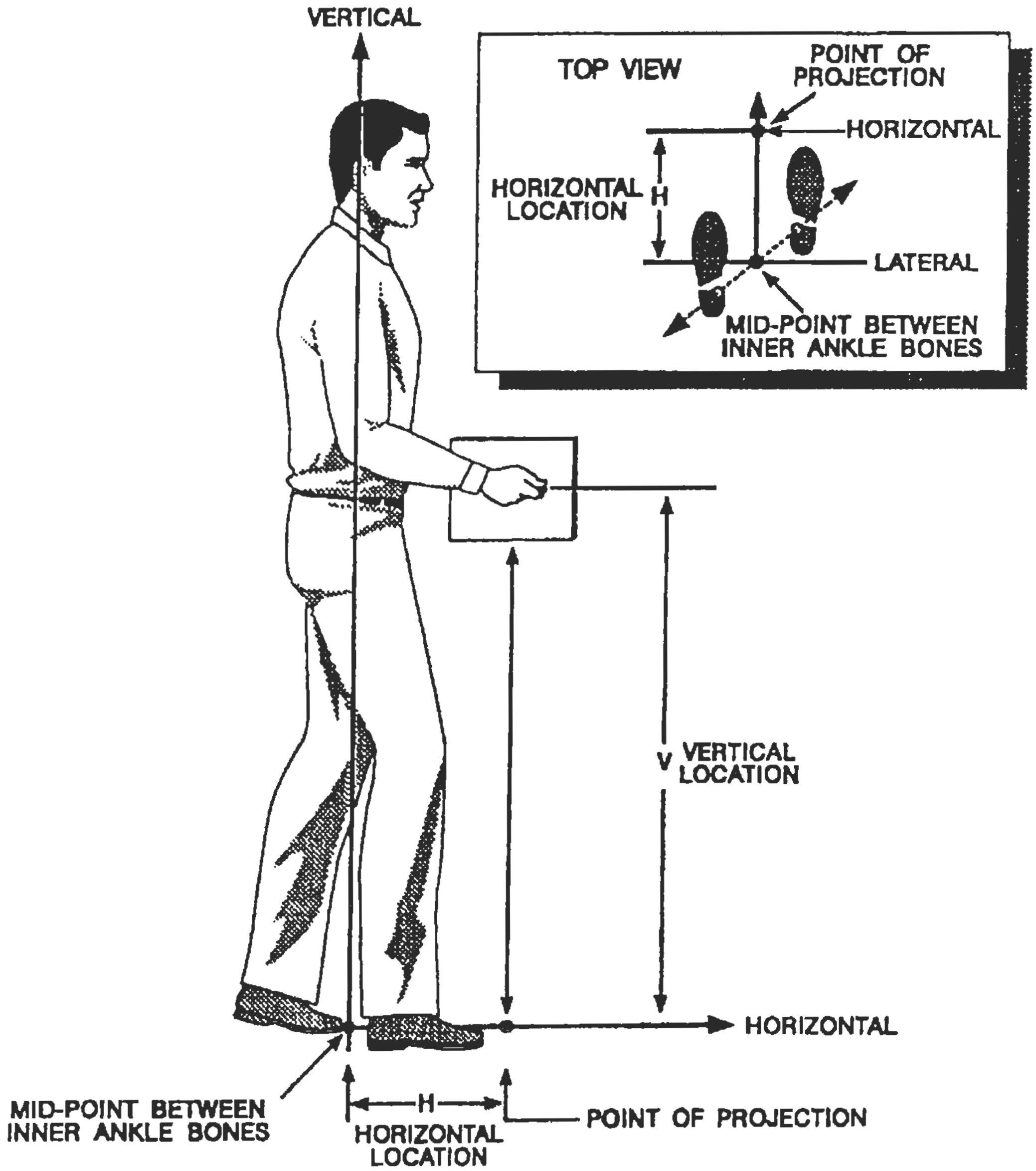


Figure 2. Graphic representation of hand locations. Horizontal location refers to hand distance and vertical location refers to hand height.

<u>NOTE:</u> In cases where hand distance <u>*absolutely cannot be measured directly*</u>, then it may be estimated as follows:

(1) When hand height at start or end of lift/lower is ≥ 10 inches: Hand distance = $8 + W/2$

(2) When hand height at start or end of lift/lower is < 10 inches: Hand distance = $10 + W/2$

W is the width of the container.

2.3.d Significant Control at Destination (Yes or No):

Significant control is "Yes" when the worker must do one or more of the following:

a. Re-grasp the load near the destination of the lift/lower.

b. Momentarily hold the object ("hover") at the destination.

c. Position or guide the load at the destination.

If significant control is required, enter a Yes on the data collection sheet. If significant control is not required, then enter No.

2.3.e Duration (Short, Moderate or Long):

Duration is classified as short, moderate, or long. The durations are defined by the relationship between work time (WT) and recovery time (RT). Work time is simply the length of time during which the worker is lifting or lowering. Recovery time includes any time after the lifting/lowering task that the worker is resting or performing non-strenuous activities. The following definitions can be used:

Short duration: Tasks with ***work times of 1 hour or less (0-60 min.) followed by a recovery time of 1.2 times the task*** (i.e., $RT/WT \geq 1.2$).

Moderate duration: Tasks with ***durations between 1 and 2 hours (61-120 Min.) followed by a recovery period of at least 0.3 times the work time*** ($RT/WT \geq 0.3$).

Long duration: Tasks with ***durations between 2-8 hours (>120 min.)*** with standard breaks (coffee, lunch, etc.).

EXAMPLES:

It should be noted that if the recovery time is not long enough as described for short- and moderate-duration tasks, it is disregarded for calculating duration. This is illustrated in the examples below.

(1) A worker lifts continuously for 30 minutes followed by 10 minutes of light work (i.e., recovery), then a 45-minute period during which lifts are performed. Since the 10-minute recovery time (10 min.) is less than 1.2 times the work time (36), the recovery time is disregarded. The 30 and 45 min. periods are combined yielding a 75 minute period which is classified as moderate duration.

30 minutes of lifting, 10 minutes rest, 45 minutes of lifting

10 minutes is less than 1.2 times the first work period, so rest period is ign

Work time is equal to 75 minutes

No strenuous work afterwards - Duration is Moderate
45 minutes + of work afterwards - Duration is Long

(2) A worker performs lifts and lowers for 100 minutes followed by 10 minutes of rest. Following the break, the worker lifts continuously for 3 hours. Since the rest period (10 min.) is not at least 0.3 times the first work period (100 minutes), the break is disregarded and a work period of 100 + 180 min. = 280 min., or slightly less than 5 hours is used. Thus, the task is classified as having a long duration.

NOTE: If a rest time is not sufficient for either the short or medium duration definitions, the rest time should be ignored, i.e. treat the determination as if there was no break. Simply combine the time of the tasks before and after the break and determine the duration of the "new" task.

2.3.f Coupling (Good, Fair or Poor):

Coupling is classified into 1 of 3 categories: Good, Fair and Poor. Figure 3 provides a decision tree for determining the coupling category. The table in the Appendix and notes underneath it provide additional details about how to correctly characterize the coupling of an object.

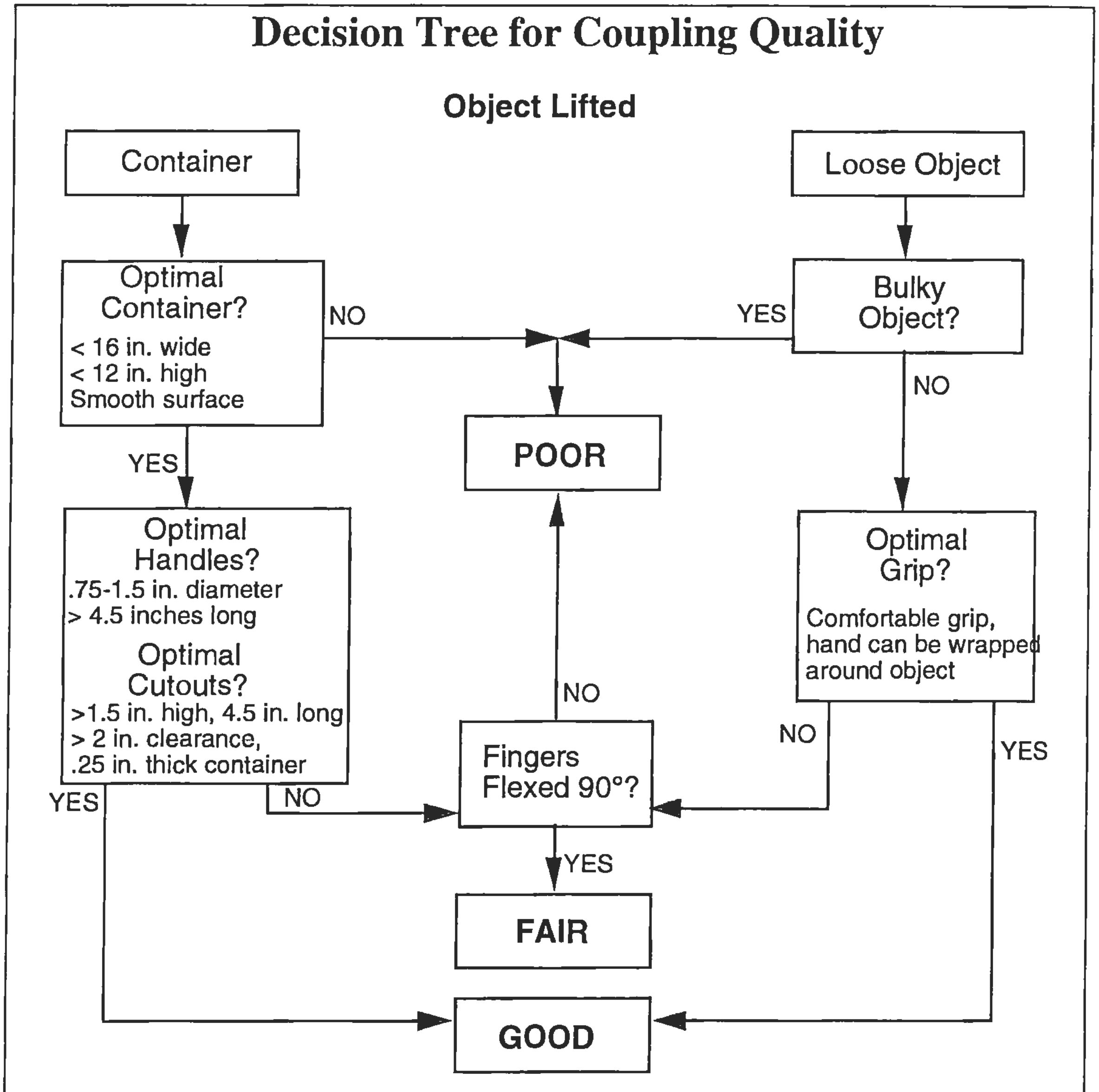


Figure 3. Decision tree for deciding on coupling quality.

2.3.g Angle of Twist (i.e., Twisting) (degrees):

Record the angle of twist (asymmetry) in degrees for each component. Please be cautious in that this angle refers to load asymmetry and not trunk twisting. As shown in

Figure 4 angle A is defined as the angle between the sagittal plane and the center of the load. Measure to the closest degree using the protractor.

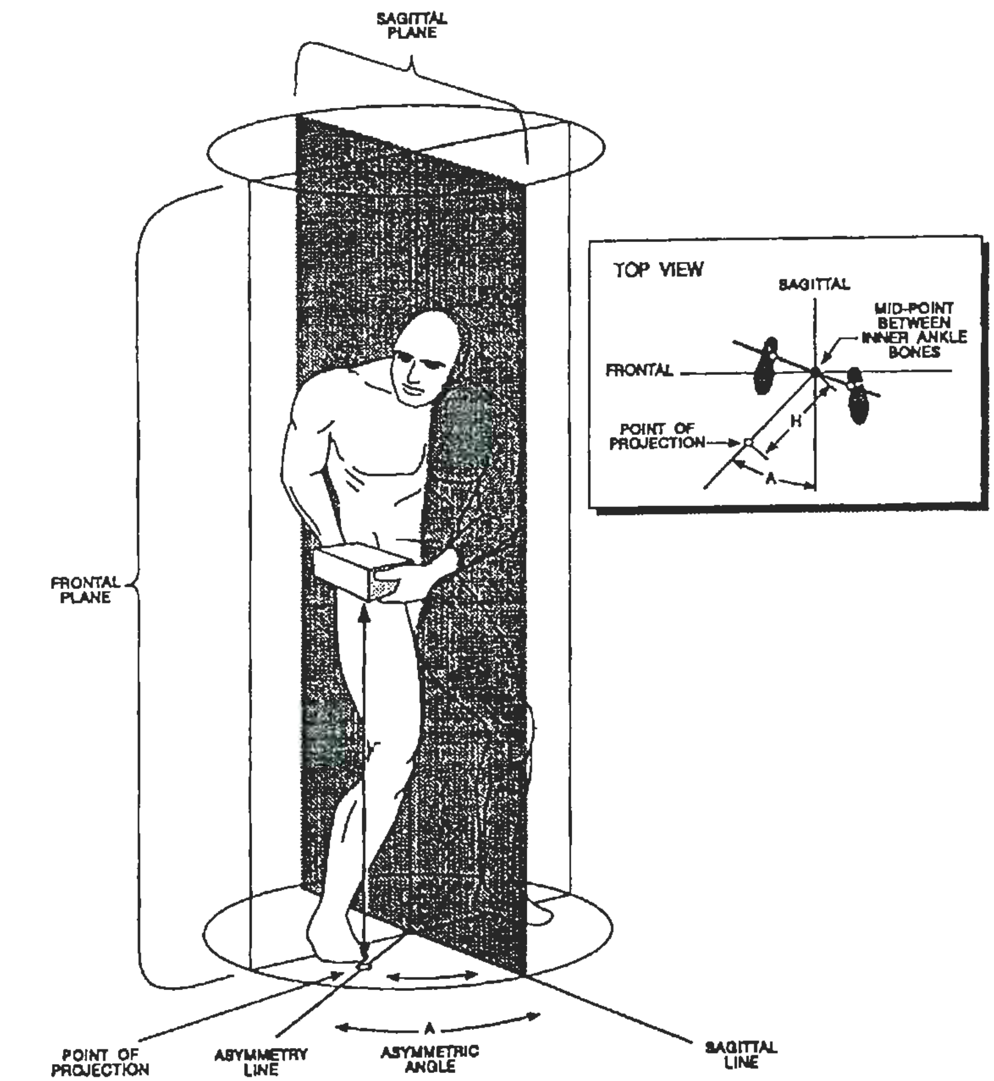


Figure 4. Definition of angle of twist (asymmetry).

The sagittal line can be estimated by placing your feet in a position similar to the worker's feet at the origin/destination of the lift. The sagittal line is a line extending directly in front of you.

2.3.h Task Frequency (lifts/lowers per minute):

THIS IS VERY DIFFERENT FROM CompuTask®.

Standard/Variable Weight/Job Rotation Worksheets- Task frequency is calculated using a 15 minute observation period. The number of lifts/lowers performed during the 15 minute period is divided by 15 to provide the frequency in lifts/lowers per minute. NOTE THAT FREQUENCY IS LIFTS PER MINUTE, NOT 1 LIFT EVERY X SEC./MIN. AS IS THE CASE WITH *CompuTask®*. In cases where the task is machine-paced or very steady, you may not need 15 minutes to obtain an accurate estimate. The frequency must be determined for EACH distinct task. For example, unloading a pallet with 8 levels requires 8 distinct types of lifts/lowers with different parameters. In such a case, the frequency is determined for each of the individual distinct tasks (levels) and not the overall task. This is illustrated by the example provided later.

Warehouse/Complex Job Worksheet- Pick frequency is calculated by using a 15 minute observation period of active picking. The number of picks performed during the 15 minute period is recorded to provide the frequency in picks per minute. Also, if possible, obtain production standards or other information which specifies work rates.

2.3.i Cycle Time (minutes):

Cycle time is particularly relevant for repetitive tasks. Cycle time refers to the time it takes to do one cycle, i.e. how long it takes to do a sequence of tasks before starting over again. For example, if a worker lifts stock and loads a machine, performs several drilling operations, then unloads the machine and lowers the stock, the cycle time begins when the worker begins to lift the stock and ends when the worker places the stock back where it was. Thus, cycle time does not necessarily include lifting, lowering, etc. exclusively, but also includes other tasks.

2.4 Pushing and Pulling:

2.4.a Pushing and pulling forces:

These would normally need to be measured using the material handling kit's spring scale. For pushing components, measure the force by pulling, since the force required would be the same.

Initial force: Enter the amount of force necessary to start the object moving. Take three measurements and enter the highest value in the column. Keep in mind that initial force may be highest in areas where floor conditions are poor.

Sustained force: Enter the amount of pushing or pulling force necessary to keep the object moving. Since the scale will fluctuate somewhat, take three measurements and enter the average in this column.

2.4.b Pushing/pulling distance (feet):

Record the distance load is pushed (closest foot).

2.4.c Pushing/pulling frequency (pushes/pulls per minute):

Frequency is calculated the same as for lifting/lowering tasks.

2.4.d Hand height (inches):

Record the height of knuckles above the ground.

2.5 Holding:

2.5.a Object weight being held (pounds):

If the weight of the object is not indicated on the object itself, it can be determined by weighing the object on a scale in the facility, or by using the spring scale in our kit. Enter the weight to the closest pound.

2.5.b Holding time (Minutes)

Record the length of time object is held. Use 1 decimal place of accuracy. This time should be entered in the Duration column on the Task Measurement Sheet.

2.5.c Holding frequency (holds per minute)

Frequency is calculated the same as for lifting/lowering tasks.

2.5.d Hand height (inches)

Record the height of knuckles above the ground.

2.6 Carrying:

2.6.a Weight being carried (pounds)

If the weight of the object is not indicated on the object itself, it can be determined by weighing the object on a scale in the facility, or by using the spring scale in our kit. Enter the weight to the closest pound.

2.6.b Carry distance (feet)

Record the distance the load is carried.

2.6.c Carrying frequency (holds per minute):

Frequency is calculated the same as for lifting/lowering tasks.

2.6.d Hand height (inches):

Record the height of knuckles above the ground.

3.0 Completing Variable Weight Job Worksheets

As was mentioned earlier, "Variable Weight Jobs" refers to those jobs in which the MMH tasks performed remain relatively stable, but the weight changes.

If the 'Object Weight' for a task varies, a 'V' should be placed on the task worksheet and an entry for the task should be included on the Variable Weight Worksheet. This sheet requires the following information:

(1) the average object weight;

(2) the maximum object weight; and

(3) the percentage of objects lifted in the following categories (percentages should sum to 100):

0 to 20 pounds,

21 to 40 pounds,

41 to 60 pounds,

61 to 80 pounds,

81 to 100 pounds,

Over 100 pounds.

If possible, this information should be obtained from available company records or objective data (production records, etc.). However, in some cases, the information will need to be obtained by asking the workers to estimate these values based upon their work experience. Estimates provided by workers are not going to be as precise as objective measurements, but will still be of value to the study. If a worker provides estimates that seem inaccurate based on your observations of the job, a supervisor should be consulted regarding the values. In the last column of the Variable Load Worksheet please indicate whether the information in the Table was obtained from objective data ('yes' in this column) or from the worker ('no' in this column). Objective data refers to production planning or scheduling data, shipping data, etc. or by actually weighing the objects using a scale.

4.0 COMPLETING WAREHOUSING /COMPLEX JOB WORKSHEETS

A task sampling procedure will be used to gather the data for warehousing operations or operations with many lifting and lowering tasks. Recall that these operations should only be included if multiple workers are performing the same job. The analysis will have to be conducted during a typical work day. It is anticipated that lifting/lowering will be the primary job of workers involved in warehousing operations, but carrying may also be a major component.

You need to make up to three critical observations for each of 15 different lifting tasks (i.e., picks) that occur during the work shift. There will be three required observations when the job requires the worker to lift or lower an item from a slot, carry the item more than two steps, and then lift or lower the item to the pallet or whatever is used to collect the items. In this case, the three observations are:

(1) The lift or lower from the slot (indicated as 1a. Initial Location (e.g. Pick Slot),

(2) The carry distance (last column), and

(3) The lift or lower to the pallet (indicated as 1b. Final Location (e.g. Pallet).

If the pallet is close enough that two steps or less are required, simply measure the lift/lower parameters for the start (origin) and end (destination) of the lift or lower.

In all cases, the tasks selected should be representative of the breadth of lifting tasks completed at the facility, but in all other ways should be randomly selected. For instance, try not to analyze 15 lifting tasks that involve items that are unusually heavy.

The subjects used in the analysis should be part of the normal work force. Information for each of the 15 different lifting tasks observed should be entered into the Warehousing/Complex Task Measurement Sheet. It is good to measure tasks performed by several different workers, i.e., try not to measure all 15 tasks from the same worker. Each sample should reflect how the individual that is being observed at the time is completing the task and should not be biased by previous observations. Object weight for the samples should reflect the object being lifted for the current task and should not be marked 'V' for variable. A completed analysis for a warehousing operation will include Warehousing/Complex Task Measurement Sheets #1 and #2 with data for the 15 different picking tasks observed for all workers that do the warehousing job.

Other MMH Tasks- In addition to collecting data on 15 different lifting tasks grouped as warehouse/complex jobs, you should also record information on other manual material handling tasks. Measure other (up to five) MMH tasks that the worker performs (e.g., restacking 60 lb. wood pallets).

Most Stressful Tasks- You will also need to obtain information on the most stressful task performed. This task MAY be included as one of the 15 different lifting tasks from page W4 - W5. Selecting the tasks that are most stressful in terms of MMH will have to be done based on your personal expertise and judgment. Work tasks that tend to be most stressful involve heavy loads, longer reaches, twisting during the lift, and high frequencies. Both the workers and their supervisors should be consulted in making this determination.

Warehouse/Complex Job Worksheet- Pick frequency is calculated by using a 15 minute observation period of active picking by one worker. A 15-minute period that approximates the average pick rate should be selected. The number of picks performed during the 15 minute period is recorded to provide the frequency in picks per minute. Also, if possible, obtain production standards or other information which specifies work rates.

Once the job data is collected, you should perform interviews on as many workers as possible that perform that job.

5.0 COLLECTING JOB ROTATION WORKSHEETS

"Job Rotation" refers to formal job rotation or situations where different sets of MMH tasks are done at different times throughout the day. For instance, a production worker may spend the better part of his/her day working on a line, but may also spend some time palletizing. Although this may not be "Job Rotation" in the strict sense, the work pattern very much resembles work that is part of formal job rotation schemes.

For jobs that involve job rotation, the following rules should be followed in completing worksheets on page 5 - 6 in the Job Rotation Packet. If the work schedule includes only two different jobs, then Task Measurement Sheet on page 5-6 should be completed. If more than two jobs are involved, you will need to determine: (1) the job that is most stressful in terms of MMH (record data on page 5, *Most Stressful Rotation*); and (2) the job involves MMH and comprises the largest percentage of the work rotation cycle (record data on page 6, *Second Most Stressful Rotation*). If all jobs are done for an equal amount of time, the first and the second most stressful MMH related jobs should be selected. Regardless of the number of jobs being performed by the worker, only two jobs should be selected for analysis.

Selecting the jobs that are most stressful in terms of MMH will have to be done based upon your personal expertise and judgment. Work tasks that tend to be most stressful involve heavy loads, longer reaches, twisting during the lift, and high frequencies. Both the workers involved in the job and their supervisors should be consulted in making this determination. Once the two rotations are selected, they should be analyzed in the same manner as standard jobs.

6.0 INJURY DATA

Please obtain a copy the OSHA 200 log at the beginning of the study for the current year, as well as the last three years if possible. You will also need to follow up with the customer contact to obtain the OSHA log at year end if customer cannot be contacted by the Research Center.

APPENDIX A

COUPLING CLASSIFICATION

GOOD	FAIR	POOR
1. For containers of optimal design, such as some boxes, crates, etc., a "Good" hand-to-object coupling would be defined as handles or hand-hold cut-outs of optimal design [see notes 1 to 3 below].	1. For containers of optimal design, a "Fair" hand-to-object coupling would be defined as handles or hand-hold cutouts of less than optimal design [see notes 1 to 4 below].	1. Containers of less than optimal design or loose parts or irregular objects that are bulky, hard to handle, or have sharp edges [see note 5 below].
2. For loose parts or irregular objects, which are not usually containerized, such as castings, stock, and supply materials, a "Good" hand-to-object coupling would be defined as a comfortable grip in which the hand can be easily wrapped around the object [see note 6 below].	2. For containers of optimal design with no handles or hand-hold cut-outs or for loose parts or irregular objects, a "Fair" hand-to-object coupling is defined as a grip in which the hand can be flexed about 90 degrees [see note 4 below].	2. Lifting non-rigid bags (i.e. bags that sag in the middle).

1. An optimal handle design has .75 - 1.5 inches diameter, = 4.5 inches length, 2 inches clearance, cylindrical shape, and a smooth, non-slip surface.

2. An optimal hand-hold cut-out has the following approximate characteristics: = 1.5 inch height, 4.5 inch length, semi-oval shape, = 2 inch clearance, smooth non-slip surface, and = 0.25 inches container thickness (e.g. double thickness cardboard).

3. An optimal container design has = 16 inches frontal length, = 12 inches height, and a smooth, non-slip surface.

4. A worker should be capable of clamping the fingers at nearly 90° under the container, such as required when lifting a cardboard box from the floor.

5. A container is considered less than optimal if it has a frontal length > 16 inches, height > 12 inches, rough or slippery surfaces, sharp edges, asymmetric center of mass, unstable contents, or requires the use of gloves. A loose object is considered bulky if the load cannot easily be balanced between the hand grasps.

6. A worker should be able to comfortably wrap the hand around the object without causing excessive wrist deviations or awkward postures, and the grip should not require excessive force.

APPENDIX B

"Standard Job" DATA COLLECTION WORKSHEETS

STANDARD JOB WORKSHEET

Evaluated by (Name)	Office		Date
Company Name	Location		SIC Code
Subject Name	Job Title (and number if any)		Department Name (and number if any)
Shift	Average Duration of Work Day (hours)	Average Duration of Work Week (Days)	Restricted Duty (Y/N)
Job Description			

Customer Contact:

Name ______________________________

Company ______________________________

Title ______________________________

Address ______________________________

____

Phone # ______________________________

Can Research Center call the customer contact directly to obtain OSHA logs? (Y/N) _________

STANDARD JOB SKETCH OF WORKPLACE

Company:________________________ Job Title:______________________________ Subject Initials:__________

STANDARD JOB TIME SCHEDULE

Company:______________________ Job Title:__________________________________ Subject Initials:_________

Task Numbers (From Pages 4 and 5)	DESCRIPTION	Time (e.g. 9:00-12:00 p.m.)

STANDARD JOB - Task Measurement Sheet 1

Company:________________________ Job Title:______________________________________ Subject Initials:__________

Task Components	Measurements and Observations (Use Material Handling Scale Kit If Needed)																
TYPE Lift Lower Push Pull Carry Hold	**Task Group (All)**	**Object Weight (Lift, Lower, Carry, Hold)**	**Hand Height (All)**		**Hand Distance Away From Body (lift, lower)**		**Significant Control (lift, lower)**	**Duration (lift, lower)**	**Coupling (lift, lower)**	**Twisting (lift, lower)**		**Task Frequency (All)**	**Pushing and Pulling Forces**		**Push Pull or Carrying Distance**	**Cycle Time**
	Letter	LB.	Start IN.	End IN.	Start IN.	End IN.	Y/N	S/M/L	G/F/P	Start DEG.	End DEG.	Per Minute	Initial LB.	Sustained LB.	FT.	MIN.
1)																
2)																
3)																
4)																
5)																
6)																
7)																
8)																
9)																
10)																
11)																
12)																
13)																
14)																

STANDARD JOB - Task Measurement Sheet 2

Company:______________________ Job Title:__________________________________ Subject Initials:_________

Task Components	Measurements and Observations (Use Material Handling Scale Kit If Needed)															
TYPE Lift Lower Push Pull Carry Hold	**Task Group (All)** Letter	**Object Weight (Lift, Lower, Carry, Hold)** LB.	**Hand Height (All)** Start IN.	End IN.	**Hand Distance Away From Body (lift, lower)** Start IN.	End IN.	**Significant Control (lift, lower)** Y/N	**Duration (lift, lower)** S/M/L	**Coupling (lift, lower)** G/F/P	**Twisting (lift, lower)** Start DEG.	End DEG.	**Task Frequency (All)** Per Minute	**Pushing and Pulling Forces** Initial LB.	Sustained LB.	**Push Pull or Carry Distance** FT.	**Cycle Time** MIN.
15)																
16)																
17)																
18)																
19)																
20)																
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23)																
24)																
25)																
26)																
27)																
28)																

Liberty Mutual Research Center for Safety and Health
Texas Tech University

Field Evaluation of MMH Criteria

Worker Survey

NAME ______________________________

SOCIAL SECURITY NUMBER ______________________

Date of Interview ____/____/____
Month Day Year

Background Information

1. Height ft________in________
2. Weight____________
3. Gender: Male _____ Female ____
4. What is your date of birth? ____/____/____
Mo. Day Yr.
5. When did you **first** start working for this employer, either permanently or temporarily?

   ______/______
   Month Year

6. What is your job title, or occupation?

   ____

5. When did you first start working **on this job**?

   ______/______
   Month Year

7. How many hours per day, on average, do you do this job? Hours ______
8. How many days per week, on average, do you do this job? Days ______

9. What is the total percent of your day normally spent doing the following activities?

Lifting ______

Lowering ______

Pushing ______

Pulling ______

Holding ______

Carrying ______

10. How much time, **per day**, on average, are you in a vehicle commuting **to and from** work?

______Hours ______Minutes

11. Have you filed a workers' compensation claim **during the last 12 months** because of back pain?

Yes_____ No___________

12. Do you exercise regularly (on average 3 or more times per week) outside of work?

Yes ___________ No ___________

13. IF YES, EXERCISE REGULARLY: What type of exercise do you do? Check **all** that apply.

Weight Lifting ________________
Running/Jogging ________________
Aerobics ________________
Golf ________________
Any Team Sport (including bowling, softball, etc.) ________________
Other (specify) ________________
____

14. Do you currently smoke cigarettes? Yes _____ No ______

15. IF YES, SMOKE: On average how many cigarettes a day do you smoke ? ______

16. IF YES, SMOKE: For how many years have you smoked? ______

17. Do you ever wear a back belt (support or brace) while doing this job?

Yes________ No__________

18. IF YES, HAVE WORN BACK BELT: When did you **first** start wearing it?

____________ ____________
Month Year

19. IF YES, HAVE WORN BACK BELT: How often do you wear your back belt? (read choices)

Always or most of the time ______

Sometimes or about half of the time ______

Very little or not at all ______

Only when handling heavy loads ______

20. IF YES, HAVE WORN BACK BELT: What type of belt do/did you wear?

Stretchable:

some types of nylon, any material that stretches when pulled ______

Non-Stretchable:

for example, belts made of webbed nylon, leather, or other non-elastic materials ______

We would like to send you a very short questionnaire (it will take 5 minutes or less) every 3 months for about a year and a half to ask about your job and about whether or not you have been injured at work. Also, we may want to call you once or twice during this period.

What is your home phone number? (________)__________
area code

What is your home address?______________________
Street Address or PO Box

____
City State Zip Code

Sometimes it is difficult to locate participants if they move or change phone numbers. To help us with this we ask for the name and address of two people who should know how to contact you in such instances (such as a family member). In case we can't reach you for some reason to ask about where you're working, may we have the name, address and phone number of a close relative or friend we can contact? **We'll only use this if we can not reach you by mail or phone.**

Name: ______________________

Address: ______________________
Street Address or PO Box

____
City State Zip Code

LIBERTY MUTUAL.

The Research Center for Safety and Health
71 Frankland Road
Hopkinton, MA 01748
(508) 435-9061

Liberty Mutual Research Center for Safety and Health
Informed Consent Form

Purpose of Study

The purpose of this study is to evaluate and describe tasks and workplaces where materials are handled manually. Workers performing the manual tasks will be interviewed. The primary goal of the study is to determine the relationships between job demands and future occurrences of injury. Eventually, the results of the study will be used to (re)design workplaces to minimize the probability of being injured.

Benefits

You will receive no direct benefit from your participation in this study but the information gained may result in the improved health of workers who perform manual handling tasks.

Risks

Since you will be doing your regular job, there will not be any risks beyond those you encounter under normal working conditions.

Participation

Your participation in this study is strictly voluntary. You are free to decline to participate in the study without penalty or question. You are also free to decline to answer any questions. You will be under no pressure to continue. If you agree to participate you will be interviewed, observed doing your job, and measurements will be taken of a variety of your work tasks. General health and employment information will also be collected. We would like to send you a very short questionnaire (takes less than 5 minutes to fill out) every 3 months during the next 1 1/2 years to ask whether or not you are working in the same job and to ask about any recent injuries at work. Also, if you are willing, we may wish to call you once or twice during the 1 1/2 year period to ask you more details about your responses to the questions.

Videotaping

In this study, you may be videotaped as you perform your job for research purposes only.

____________ Initials

LIBERTY MUTUAL.

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71 Frankland Road
Hopkinton, MA 01748
(508) 435-9061

Confidentiality

Our policy is to consider test data to be privileged. All data collected will be identified by a subject number and not your name. Individual personal data gathered through the questions will not be shared with your employer or anyone else. The questionnaire data collected are strictly for research purposes. Any published work will not refer to you by name, rather the results will be presented in a manner that summarizes or averages the data.

Supervision

This study will be directly supervised by Patrick Dempsey, Ph.D. Questions or comments about participation should be directed to Dr. Dempsey at (508) 435-9061 (x309). If, after contacting the above person, you do not feel that your concerns were adequately addressed, you may contact Mr. Jim Klock, Director of Operations for the Research Center at (508) 435-9061 (x303).

Consent

Please read the following statement and sign on the line below if you agree to participate in the study.

I have read this document or it has been read to me and understand the purpose of the study, and what is expected of me if I agree to participate. By signing this consent form, I agree freely to participate in this study without any pressure having been placed on me to do so.

______________________	______________________
Signature	*Date*
______________________	______________________
Witness	*Date*

APPENDIX C

"Variable Weight Job" DATA COLLECTION WORKSHEETS

VARIABLE WEIGHT JOB WORKSHEET

Evaluated by (Name)	Office	Date	
Company Name	Location	SIC Code	
Subject Name	Job Title (and number if any)	Department Name (and number if any)	
Shift	Average Duration of Work Day (hours)	Average Duration of Work Week (Days)	Restricted Duty (Y/N)
Job Description			

Customer Contact:

Name ______________________________

Company ______________________________

Title ______________________________

Address ______________________________

____

Phone # ______________________________

Can Research Center call the customer contact directly to obtain OSHA logs? (Y/N) ________

VARIABLE WEIGHT SKETCH OF WORKPLACE

Company:____________________ Job Title:________________________ Subject Initials:________

VARIABLE WEIGHT TIME SCHEDULE

Company:____________________ Job Title:______________________________ Subject Initials:________

Task Numbers (From Pages 4 and 5)	DESCRIPTION	Time (e.g. 9:00-12:00 p.m.)

VARIABLE WEIGHT - Task Measurement Sheet 1

Company:______________________ Job Title:__________________________________ Subject Initials:_________

For tasks with variable weight, enter a "V" in the Object Weight field.

Task Components	Measurements and Observations (Use Material Handling Scale Kit If Needed)																
TYPE Lift Lower Push Pull Carry Hold	**Task Group (All)**	**Object Weight (Lift, Lower, Carry, Hold)**	**Hand Height (All)**		**Hand Distance Away From Body (lift, lower)**		**Significant Control (lift, lower)**	**Duration (lift, lower)**	**Coupling (lift, lower)**	**Twisting (lift, lower)**		**Task Frequency (All)**	**Pushing and Pulling Forces**		**Push Pull or Carry Distance**	**Cycle Time**
	Letter	LB.	Start IN.	End IN.	Start IN.	End IN.	Y/N	S/M/L	G/F/P	Start DEG.	End DEG.	Per Minute	Initial LB.	Sustained LB.	FT.	MIN.
1)																
2)																
3)																
4)																
5)																
6)																
7)																
8)																
9)																
10)																
11)																
12)																
13)																
14)																

VARIABLE WEIGHT - Task Measurement Sheet 2

Company:________________________ Job Title:_____________________________________ Subject Initials:__________

For tasks with variable weight, enter a "V" in the Object Weight field.

Task Components	Measurements and Observations (Use Material Handling Scale Kit If Needed)															
TYPE Lift Lower Push Pull Carry Hold	**Task Group (All)**	**Object Weight (Lift, Lower, Carry, Hold)**	**Hand Height (All)**		**Hand Distance Away From Body (lift, lower)**		**Significant Control (lift, lower)**	**Duration (lift, lower)**	**Coupling (lift, lower)**	**Twisting (lift, lower)**		**Task Frequency (All)**	**Pushing and Pulling Forces**		**Push Pull or Carry Distance**	**Cycle Time**
	Letter	LB.	Start IN.	End IN.	Start IN.	End IN.	Y/N	S/M/L	G/F/P	Start DEG.	End DEG.	Per Minute	Initial LB.	Sustained LB.	FT.	MIN.
15)																
16)																
17)																
18)																
19)																
20)																
21)																
22)																
23)																
24)																
25)																
26)																
27)																
28)																

VARIABLE WEIGHT WORKSHEET

Company:________________________ Job Title:_________________________________ Subject Initials:__________

Measurements and Observations (Use Objective Data or Estimates from the Workers)										
Variable Weight Task # (From Pages 4 and 5)	**Average Object Weight** LB.	**Maximum Object Weight** LB.	Percentage of Loads in the Following Categories							**Objective Data?** Yes/No
			0 to 20 LB. %	**21 to 40 LB.** %	**41 to 60 LB.** %	**61 to 80 LB.** %	**81 to 100 LB.** %	**Over 100 LB.** %	**TOTAL** %	
									100	
									100	
									100	
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									100	
									100	
									100	
									100	
									100	
									100	
									100	
									100	
									100	
									100	

Liberty Mutual Research Center for Safety and Health
Texas Tech University

Field Evaluation of MMH Criteria

Worker Survey

NAME ______________________________

SOCIAL SECURITY NUMBER ______________________

Date of Interview ______/______/______
Month Day Year

Background Information

1. Height ft________in________

2. Weight__________

3. Gender: Male _____ Female ____

4. What is your date of birth? ______/______/______
Mo. Day Yr.

5. When did you **first** start working for this employer, either permanently or temporarily?

______/______
Month Year

6. What is your job title, or occupation?

____

5. When did you first start working **on this job**?

______/______
Month Year

7. How many hours per day, on average, do you do this job? Hours ______

8. How many days per week, on average, do you do this job? Days ______

9. What is the total percent of your day normally spent doing the following activities?

Lifting ______

Lowering ______

Pushing ______

Pulling ______

Holding ______

Carrying ______

10. How much time, **per day**, on average, are you in a vehicle commuting **to and from** work?

______Hours ______Minutes

11. Have you filed a workers' compensation claim **during the last 12 months** because of back pain?

Yes_____ No__________

12. Do you exercise regularly (on average 3 or more times per week) outside of work?

Yes __________ No __________

13. IF YES, EXERCISE REGULARLY: What type of exercise do you do? Check **all** that apply.

Weight Lifting ______________
Running/Jogging ______________
Aerobics ______________
Golf ______________
Any Team Sport (including bowling, softball, etc.) ______________
Other (specify) ______________

____

14. Do you currently smoke cigarettes? Yes _____ No ______

15. IF YES, SMOKE: On average how many cigarettes a day do you smoke ? ______

16. IF YES, SMOKE: For how many years have you smoked? ______

17. Do you ever wear a back belt (support or brace) while doing this job?

Yes________ No__________

18. IF YES, HAVE WORN BACK BELT: When did you **first** start wearing it?

____________ ____________
Month Year

19. IF YES, HAVE WORN BACK BELT: How often do you wear your back belt? (read choices)

Always or most of the time ________

Sometimes or about half of the time ________

Very little or not at all ________

Only when handling heavy loads ________

20. IF YES, HAVE WORN BACK BELT: What type of belt do/did you wear?

Stretchable:

some types of nylon, any material that stretches when pulled ______

Non-Stretchable:

for example, belts made of webbed nylon, leather, or other non-elastic materials ______

We would like to send you a very short questionnaire (it will take 5 minutes or less) every 3 months for about a year and a half to ask about your job and about whether or not you have been injured at work. Also, we may want to call you once or twice during this period.

What is your home phone number? (____________)____________
area code

What is your home address?______________________________
Street Address or PO Box

____
City State Zip Code

Sometimes it is difficult to locate participants if they move or change phone numbers. To help us with this we ask for the name and address of two people who should know how to contact you in such instances (such as a family member). In case we can't reach you for some reason to ask about where you're working, may we have the name, address and phone number of a close relative or friend we can contact? **We'll only use this if we can not reach you by mail or phone.**

Name: ______________________________

Address: ______________________________
Street Address or PO Box

____
City State Zip Code

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Benefits
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Risks
Since you will be doing your regular job, there will not be any risks beyond those you encounter under normal working conditions.

Participation
Your participation in this study is strictly voluntary. You are free to decline to participate in the study without penalty or question. You are also free to decline to answer any questions. You will be under no pressure to continue. If you agree to participate you will be interviewed, observed doing your job, and measurements will be taken of a variety of your work tasks. General health and employment information will also be collected. We would like to send you a very short questionnaire (takes less than 5 minutes to fill out) every 3 months during the next 1 1/2 years to ask whether or not you are working in the same job and to ask about any recent injuries at work. Also, if you are willing, we may wish to call you once or twice during the 1 1/2 year period to ask you more details about your responses to the questions.

Videotaping
In this study, you may be videotaped as you perform your job for research purposes only.

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Our policy is to consider test data to be privileged. All data collected will be identified by a subject number and not your name. Individual personal data gathered through the questions will not be shared with your employer or anyone else. The questionnaire data collected are strictly for research purposes. Any published work will not refer to you by name, rather the results will be presented in a manner that summarizes or averages the data.

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Please read the following statement and sign on the line below if you agree to participate in the study.

I have read this document or it has been read to me and understand the purpose of the study, and what is expected of me if I agree to participate. By signing this consent form, I agree freely to participate in this study without any pressure having been placed on me to do so.

________________________ ____________________

Signature *Date*

________________________ ____________________

Witness *Date*

Appendix D

"Warehousing/Complex Job" DATA COLLECTION WORKSHEETS

WAREHOUSING/COMPLEX JOB WORKSHEET

Evaluated by (Name)	Office	Date	
Company Name	Location	SIC Code	
Subject Name	Job Title (and number if any)	Department Name (and number if any)	
Shift	Average Duration of Work Day (hours)	Average Duration of Work Week (Days)	Restricted Duty (Y/N)
Job Description			

Customer Contact:

Name ____

Company ____

Title ____

Address ____

____

Phone # ____

Can Research Center call the customer contact directly to obtain OSHA logs? (Y/N) ________

WAREHOUSING/COMPLEX JOB SKETCH OF WORKPLACE

Company:____________________ Job Title:________________________ Subject Initials:________

WAREHOUSING/COMPLEX JOB TIME SCHEDULE

Company:________________________ Job Title:____________________________________ Subject Initials:__________

JOB ACTIVITY (e.g. Order Picking; Paper work)	DECRIPTION OF ACTIVITY	Time (e.g. 9:00-12:00 p.m)

WAREHOUSING/COMPLEX JOB- Task Measurement Sheet 1

Company:________________________ Job Title:_____________________________________ Subject Initials:__________

	Measurements and Observations (Use Material Handling Scale Kit If Needed)										
Pick/Object Number	**TYPE** Lift/Lower	**Object Weight**	**Hand Height** START	END	**Hand Distance** START	END	**Sig. Control** Y/N	**Coupling** G/F/P	**Twisting (DEG)** START	END	**Carrying Dist.** FT.
1a. Initial. Location (e.g. Pick Slot)		lb	in	in	in	in			deg	deg	
1b. Final Location (e.g. Pallet)											
2a. Initial. Location											
2b. Final Location											
3a. Initial. Location											
3b. Final Location											
4a. Initial. Location											
4b. Final Location											
5a. Initial. Location											
5b. Final Location											
6a. Initial. Location											
6b. Final Location											
7a. Initial. Location											
7b. Final Location											
8a. Initial. Location											
8b. Final Location											
9a. Initial. Location											
9b. Final Location											
10a. Initial. Location											
10b. Final Location											

WAREHOUSING/COMPLEX JOB- Task Measurement Sheet 2

Company:________________________ Job Title:_____________________________________ Subject Initials:__________

	Measurements and Observations (Use Material Handling Scale Kit If Needed)										
Pick/Object Number	**TYPE** Lift/Lower	**Object Weight**	**Hand Height** START	END	**Hand Distance** START	END	**Sig. Control** Y/N	**Coupling** G/F/P	**Twisting (DEG)** START	END	**Carrying Dist.** FT.
11a. Initial. Location (e.g. Pick Slot)		lb	in	in	in	in			deg	deg	
11b. Final Location (e.g. Pallet)											
12a. Initial. Location											
12b. Final Location											
13a. Initial. Location											
13b. Final Location											
14a. Initial. Location											
14b. Final Location											
15a. Initial. Location											
15b. Final Location											

SPECIAL WAREHOUSE FREQUENCY CALCULATION (Picks Per Minute):

Number of Picks Observed in 15 Minute Observation Period:__________

AND (If Available)

Calculated Rate Based on Daily Picking Info:________________
Source of Information (e.g., work standards, historical average, etc.):__________

OTHER MMH TASKS:

Measure other (up to FIVE) major MMH tasks that the workers perform besides the typical task measured above (order picking).

TYPE Lift Lower Push Pull Carry Hold	Object Weight (Lift, Lower, Carry, Hold) LB.	Hand Height Start IN.	 End IN.	Hand Distance Away From Body (lift, lower) Start IN.	 End IN.	Significant Control (lift, lower) Y/N	Duration (lift, lower) S/M/L	Coupling (lift, lower) G/F/P	Twisting (lift, lower) Start DEG.	 End DEG.	Task Frequency Per Minute	Pushing and Pulling Forces Initial LB.	 Sustained LB.	Push Pull or Carrying Distance FT.
1														
2														
3														
4														
5														

MOST STRESSFUL TASK:

Task (e.g. Picking Bags of Dog Food):____

Was it Measured Above? Y/N_______ If NO, Measure the appropriate task Information below:

TYPE Lift Lower Push Pull Carry Hold	Object Weight (Lift, Lower, Carry, Hold) LB.	Hand Height Start IN.	 End IN.	Hand Distance Away From Body (lift, lower) Start IN.	 End IN.	Significant Control (lift, lower) Y/N	Duration (lift, lower) S/M/L	Coupling (lift, lower) G/F/P	Twisting (lift, lower) Start DEG.	 End DEG.	Task Frequency Per Minute	Pushing and Pulling Forces Initial LB.	 Sustained LB.	Push Pull or Carrying Distance FT.

Liberty Mutual Research Center for Safety and Health
Texas Tech University

Field Evaluation of MMH Criteria

Worker Survey

NAME ____

SOCIAL SECURITY NUMBER ___________________________

Date of Interview ______/______/______
Month Day Year

Background Information

1. Height ft__________in________

2. Weight_______________

3. Gender: Male _____ Female ____

4. What is your date of birth? ______/______/______
Mo. Day Yr.

5. When did you **first** start working for this employer, either permanently or temporarily?

________/________
Month Year

6. What is your job title, or occupation?

____

5. When did you first start working **on this job**?

________/________
Month Year

7. How many hours per day, on average, do you do this job? Hours _______

8. How many days per week, on average, do you do this job? Days _______

9. What is the total percent of your day normally spent doing the following activities?

Lifting ______

Lowering ______

Pushing ______

Pulling ______

Holding ______

Carrying ______

10. How much time, **per day**, on average, are you in a vehicle commuting **to and from** work?

______Hours ______Minutes

11. Have you filed a workers' compensation claim **during the last 12 months** because of back pain?

Yes_____ No___________

12. Do you exercise regularly (on average 3 or more times per week) outside of work?

Yes ___________ No __________

13. IF YES, EXERCISE REGULARLY: What type of exercise do you do? Check **all** that apply.

Weight Lifting ____________________
Running/Jogging ____________________
Aerobics ____________________
Golf ____________________
Any Team Sport (including bowling, softball, etc.) ____________________
Other (specify) ____________________
____

14. Do you currently smoke cigarettes? Yes _____ No ______

15. IF YES, SMOKE: On average how many cigarettes a day do you smoke ? ______

16. IF YES, SMOKE: For how many years have you smoked? ______

17. Do you ever wear a back belt (support or brace) while doing this job?

Yes________ No__________

18. IF YES, HAVE WORN BACK BELT: When did you **first** start wearing it?

____________ ____________
Month Year

19. IF YES, HAVE WORN BACK BELT: How often do you wear your back belt? (read choices)

Always or most of the time ___________

Sometimes or about half of the time ___________

Very little or not at all ___________

Only when handling heavy loads ___________

20. IF YES, HAVE WORN BACK BELT: What type of belt do/did you wear?

Stretchable:

some types of nylon, any material that stretches when pulled ________

Non-Stretchable:

for example, belts made of webbed nylon, leather, or other non-elastic materials ________

We would like to send you a very short questionnaire (it will take 5 minutes or less) every 3 months for about a year and a half to ask about your job and about whether or not you have been injured at work. Also, we may want to call you once or twice during this period.

What is your home phone number? (________________)________________
area code

What is your home address?____
Street Address or PO Box

____
City State Zip Code

Sometimes it is difficult to locate participants if they move or change phone numbers. To help us with this we ask for the name and address of two people who should know how to contact you in such instances (such as a family member). In case we can't reach you for some reason to ask about where you're working, may we have the name, address and phone number of a close relative or friend we can contact? **We'll only use this if we can not reach you by mail or phone.**

Name: ____

Address: ____
Street Address or PO Box

____
City State Zip Code

LIBERTY
MUTUAL.

The Research Center for Safety and Health
71 Frankland Road
Hopkinton, MA 01748
(508) 435-9061

Liberty Mutual Research Center for Safety and Health
Informed Consent Form

Purpose of Study
The purpose of this study is to evaluate and describe tasks and workplaces where materials are handled manually. Workers performing the manual tasks will be interviewed. The primary goal of the study is to determine the relationships between job demands and future occurrences of injury. Eventually, the results of the study will be used to (re)design workplaces to minimize the probability of being injured.

Benefits
You will receive no direct benefit from your participation in this study but the information gained may result in the improved health of workers who perform manual handling tasks.

Risks
Since you will be doing your regular job, there will not be any risks beyond those you encounter under normal working conditions.

Participation
Your participation in this study is strictly voluntary. You are free to decline to participate in the study without penalty or question. You are also free to decline to answer any questions. You will be under no pressure to continue. If you agree to participate you will be interviewed, observed doing your job, and measurements will be taken of a variety of your work tasks. General health and employment information will also be collected. We would like to send you a very short questionnaire (takes less than 5 minutes to fill out) every 3 months during the next 1 1/2 years to ask whether or not you are working in the same job and to ask about any recent injuries at work. Also, if you are willing, we may wish to call you once or twice during the 1 1/2 year period to ask you more details about your responses to the questions.

Videotaping
In this study, you may be videotaped as you perform your job for research purposes only.

______________ Initials

LIBERTY MUTUAL.

The Research Center for Safety and Health
71 Frankland Road
Hopkinton, MA 01748
(508) 435-9061

Confidentiality
Our policy is to consider test data to be privileged. All data collected will be identified by a subject number and not your name. Individual personal data gathered through the questions will not be shared with your employer or anyone else. The questionnaire data collected are strictly for research purposes. Any published work will not refer to you by name, rather the results will be presented in a manner that summarizes or averages the data.

Supervision
This study will be directly supervised by Patrick Dempsey, Ph.D. Questions or comments about participation should be directed to Dr. Dempsey at (508) 435-9061 (x309). If, after contacting the above person, you do not feel that your concerns were adequately addressed, you may contact Mr. Jim Klock, Director of Operations for the Research Center at (508) 435-9061 (x303).

Consent
Please read the following statement and sign on the line below if you agree to participate in the study.

I have read this document or it has been read to me and understand the purpose of the study, and what is expected of me if I agree to participate. By signing this consent form, I agree freely to participate in this study without any pressure having been placed on me to do so.

_______________________ _______________________
Signature *Date*

_______________________ _______________________
Witness *Date*

APPENDIX E

"Job Rotation" DATA COLLECTION WORKSHEETS

JOB ROTATION WORKSHEET

Evaluated by (Name)	Office	Date	
Subject Name	Company Name	Location	SIC Code
Shift	Average Duration of Work Day (Hours)	Average Duration of Work Week (Days)	Restricted Duty (Y/N)

Rotation #	Job Title (and # if any)	Department Name (and # if any)	Rotation Schedule (Hours/Day or Hours/Week)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Customer Contact:

Name ______________________________

Company ______________________________

Title ______________________________

Address ______________________________

____

Phone # ______________________________

Can Research Center call the customer contact directly to obtain OSHA logs? (Y/N) _________

JOB ROTATION DESCRIPTION

Rotation #	Job Title (and # if any)	Department Name (and # if any)	Description (Indicate (1) *most stressful job*, (2) *most frequent* or *second most stressful* job)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

JOB ROTATION SKETCH OF WORKPLACE

Company:________________________ Job Title:_____________________________ Subject Initials:__________

JOB ROTATION TIME SCHEDULE

Company:______________________ Job Title:__________________________________ Subject Initials:_________

Job Rotation #	TASK DESCRIPTION	Time (e.g. 9:00-12:00 p.m.)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Job Rotation - MOST stressful rotation- Task Measurement Sheet

Company:__________________ Subject Initials:__________ Job Rotation Title (Rotation #):____________________________________

Department (#).:______________________________

Task Components	Measurements and Observations (Use Material Handling Scale Kit If Needed)																
TYPE Lift Lower Push Pull Carry Hold	**Task Group (All)**	**Object Weight (Lift, Lower, Carry, Hold)**	**Hand Height (All)**		**Hand Distance Away From Body (lift, lower)**		**Significant Control (lift, lower)**	**Duration (lift, lower)**	**Coupling (lift, lower)**	**Twisting (lift, lower)**		**Task Frequency (All)**	**Pushing and Pulling Forces**		**Push Pull or Carrying Distance**	**Cycle Time**
			Start	End	Start	End				Start	End	Per	Initial	Sustained		
	Letter	LB.	IN.	IN.	IN.	IN.	Y/N	S/M/L	G/F/P	DEG.	DEG.	Minute	LB.	LB.	FT.	MIN.
1)																
2)																
3)																
4)																
5)																
6)																
7)																
8)																
9)																
10)																
11)																
12)																
13)																
14)																

Job Rotation - MOST OFTEN or SECOND most stressful rotation- Task Measurement Sheet

Company:__________________ Subject Initials:__________ Job Rotation Title (Rotation #):____________________________________

Department (#).:______________________________

Task Components	Measurements and Observations (Use Material Handling Scale Kit If Needed)															
TYPE Lift Lower Push Pull Carry Hold	**Task Group (All)**	**Object Weight (Lift, Lower, Carry, Hold)**	**Hand Height (All)**		**Hand Distance Away From Body (lift, lower)**		**Significant Control (lift, lower)**	**Duration (lift, lower)**	**Coupling (lift, lower)**	**Twisting (lift, lower)**		**Task Frequency (All)**	**Pushing and Pulling Forces**		**Push Pull or Carrying Distance**	**Cycle Time**
	Letter	LB.	Start IN.	End IN.	Start IN.	End IN.	Y/N	S/M/L	G/F/P	Start DEG.	End DEG.	Per Minute	Initial LB.	Sustained LB.	FT.	MIN.
1)																
2)																
3)																
4)																
5)																
6)																
7)																
8)																
9)																
10)																
11)																
12)																
13)																
14)																

Liberty Mutual Research Center for Safety and Health
Texas Tech University

Field Evaluation of MMH Criteria

Worker Survey

NAME ______________________________

SOCIAL SECURITY NUMBER ______________________

Date of Interview ______/______/______
Month Day Year

Background Information

1. Height ft________in________

2. Weight____________

3. Gender: Male _____ Female ____

4. What is your date of birth? ______/______/______
Mo. Day Yr.

5. When did you **first** start working for this employer, either permanently or temporarily?

______/______
Month Year

6. What is your job title, or occupation?

____

5. When did you first start working **on this job**?

______/______
Month Year

7. How many hours per day, on average, do you do this job? Hours _______

8. How many days per week, on average, do you do this job? Days _______

9. What is the total percent of your day normally spent doing the following activities?

Lifting ______

Lowering ______

Pushing ______

Pulling ______

Holding ______

Carrying ______

10. How much time, **per day**, on average, are you in a vehicle commuting **to and from** work?

______Hours ______Minutes

11. Have you filed a workers' compensation claim **during the last 12 months** because of back pain?

Yes_____ No__________

12. Do you exercise regularly (on average 3 or more times per week) outside of work?

Yes __________ No __________

13. IF YES, EXERCISE REGULARLY: What type of exercise do you do? Check **all** that apply.

Weight Lifting ______________
Running/Jogging ______________
Aerobics ______________
Golf ______________
Any Team Sport (including bowling, softball, etc.) ______________
Other (specify) ______________

____

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Yes________ No__________

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__________ __________
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some types of nylon, any material that stretches when pulled ______

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for example, belts made of webbed nylon, leather, or other non-elastic materials ______

We would like to send you a very short questionnaire (it will take 5 minutes or less) every 3 months for about a year and a half to ask about your job and about whether or not you have been injured at work. Also, we may want to call you once or twice during this period.

What is your home phone number? (____________)______________
area code

What is your home address?________________________________
Street Address or PO Box

____
City State Zip Code

Sometimes it is difficult to locate participants if they move or change phone numbers. To help us with this we ask for the name and address of two people who should know how to contact you in such instances (such as a family member). In case we can't reach you for some reason to ask about where you're working, may we have the name, address and phone number of a close relative or friend we can contact? **We'll only use this if we can not reach you by mail or phone.**

Name: ____

Address: ______________________________________
Street Address or PO Box

____
City State Zip Code

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Since you will be doing your regular job, there will not be any risks beyond those you encounter under normal working conditions.

Participation

Your participation in this study is strictly voluntary. You are free to decline to participate in the study without penalty or question. You are also free to decline to answer any questions. You will be under no pressure to continue. If you agree to participate you will be interviewed, observed doing your job, and measurements will be taken of a variety of your work tasks. General health and employment information will also be collected. We would like to send you a very short questionnaire (takes less than 5 minutes to fill out) every 3 months during the next 1 1/2 years to ask whether or not you are working in the same job and to ask about any recent injuries at work. Also, if you are willing, we may wish to call you once or twice during the 1 1/2 year period to ask you more details about your responses to the questions.

Videotaping

In this study, you may be videotaped as you perform your job for research purposes only.

____________ Initials

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Consent
Please read the following statement and sign on the line below if you agree to participate in the study.

I have read this document or it has been read to me and understand the purpose of the study, and what is expected of me if I agree to participate. By signing this consent form, I agree freely to participate in this study without any pressure having been placed on me to do so.

______________________ *Signature*	______________________ *Date*
______________________ *Witness*	______________________ *Date*

Appendix C

Subject and LI data set

Subject and LI data set

Subject ID	gender	height	weight	age	LI91	LI81	Exposure Hours	LB Injury?
1	F	62	110	44	25.09	12.04	39	No
4	F	62	106	38	0.98	0.64	0	No
5	F	62	114	52	0.76	0.43	0	No
6	F	67	175	39	0.70	0.51	1791	No
7	F	64	136	59	2.36	0.68	1791	No
8	F	64	140	35	2.92	2.36	0	No
9	F	63	125	32	0.86	0.54	1791	No
10	F	59	100	41	0.17	0.08	729	No
11	F	65	130	48	0.44	0.34	1791	No
12	F	62	.	35	1.93	0.90	2091	No
13	F	62	153	56	3.32	3.22	2606	No
14	F	60	.	63	5.42	0.87	4469	No
15	F	67	.	42	0.32	0.35	1925	No
16	F	63	.	63	0.86	0.84	7516	No
17	F	71	145	31	0.30	0.29	571	No
18	F	62	189	42	0.57	0.53	146	No
19	F	60	135	44	0.39	0.38	4341	No
20	F	68	170	60	0.47	0.13	7103	No
21	F	66	.	57	1.51	0.36	0	No
23	F	66	130	38	1.96	1.05	1404	No
24	F	69	.	53	0.97	0.59	6414	No
25	F	61	115	47	0.73	0.42	7392	No

26	F	62	170	46	0.85	0.52	4536	No
28	F	65	118	31	2.87	1.69	6646	No
29	F	64	135	39	2.04	1.86	6589	No
30	F	67	165	47	3.39	2.57	4617	No
31	F	69	170	36	3.47	1.68	5686	No
32	F	63	130	43	0.91	0.35	3103	No
33	F	66	146	35	0.75	0.32	1714	No
34	F	69	210	34	1.68	0.58	0	No
35	F	63	137	30	1.74	0.57	0	No
36	F	67	120	32	2.53	1.41	3217	No
37	F	66	120	48	1.16	0.87	3600	No
38	F	61	131	30	1.84	1.41	0	No
39	F	59	155	35	2.55	2.10	6486	No
40	F	62	107	37	1.36	1.01	280	No
41	F	66	120	29	0.36	0.39	5021	No
42	F	62.5	142	36	0.36	0.37	971	No
43	F	63	142	36	0.64	0.70	3734	Yes
44	F	64	185	25	0.48	0.50	2210	No
45	F	61	140	49	0.50	0.54	1305	No
46	F	68	.	37	0.79	0.72	2028	No
47	F	62	.	44	0.67	0.66	4675	No
48	F	64	240	43	0.99	0.82	4718	No
49	F	72	160	35	1.39	1.10	1117	No
50	F	67	140	.	2.06	1.77	2833	No
51	F	64	150	35	1.21	0.95	747	No
52	F	68	204	44	3.86	2.64	3423	No
53	F	71	206	37	2.42	1.33	3903	No
54	F	60	150	48	1.18	1.03	4514	No

55	F	61	148	30	2.13	1.39	6623	No
56	F	64	.	.	1.32	1.09	5651	No
57	F	63	118	28	0.85	0.60	3651	No
58	F	60	123	37	0.94	0.68	2800	No
59	F	61	125	33	0.84	0.60	74	No
60	F	67	.	38	0.96	0.66	674	No
61	F	66	130	34	0.47	0.23	1760	No
62	F	66	116	46	0.79	0.28	6371	No
63	F	66	175	42	0.82	0.61	80	No
64	F	62	175	46	0.74	0.50	6480	No
65	F	65	135	63	0.51	0.30	3874	No
66	F	63	140	35	0.76	0.53	3994	No
67	F	62	165	41	0.67	0.52	2594	No
68	F	65	.	23	0.99	0.75	577	No
69	F	62	120	40	1.26	1.03	857	No
70	F	62	160	40	5.47	1.40	1549	No
71	F	67	.	26	2.74	0.83	6526	No
72	F	70	.	32	9.72	3.89	326	No
73	F	63	110	24	0.65	0.56	1326	No
74	F	61	115	34	1.55	1.20	1326	No
75	F	66	130	54	1.34	1.04	0	No
76	F	67	140	24	2.07	1.68	1326	No
77	F	64	130	49	2.27	0.86	2029	No
78	F	67	.	41	1.58	0.81	4189	No
79	F	69	135	28	1.58	0.81	3251	No
80	F	66	160	23	1.58	0.81	2040	No
81	F	65	152	25	21.02	0.85	5589	No
82	F	67	180	22	21.02	0.85	3817	No

83	F	64	170	33	21.02	0.85	6709	No
84	F	.	.	.	21.02	0.85	6714	No
85	F	69	.	58	21.02	0.85	223	No
86	F	63	116	56	21.02	0.85	2034	No
87	F	67	.	.	2.28	1.67	1920	No
88	F	66	130	45	2.28	1.67	3491	No
89	F	66	120	39	0.13	0.08	4200	No
90	F	69	140	45	1.62	1.56	6709	No
91	F	67	210	32	2.82	1.57	6069	No
92	F	65	185	25	4.39	3.24	63	No
93	F	65	120	27	4.39	3.24	1657	No
94	F	65	145	39	7.90	0.53	6240	No
95	F	63	146	44	7.90	0.53	4274	No
96	F	64	150	46	7.90	0.53	2040	No
97	F	63	180	38	7.90	0.53	5434	No
98	F	63	126	57	2.59	0.96	5611	No
99	F	59	146	54	2.59	0.96	731	No
100	F	62	145	52	2.59	0.96	1943	No
101	F	60	185	51	2.59	0.96	1137	No
102	F	62	141	40	2.59	0.96	0	No
103	F	71	170	42	2.59	0.96	1091	No
104	F	62	118	37	2.59	0.96	3149	No
105	F	69	192	46	2.59	0.96	4651	No
106	F	60	150	28	2.44	1.75	2651	No
107	F	64	140	33	2.44	1.75	1080	No
108	F	60	156	52	1.61	0.70	302	No
109	F	62	142	40	1.00	0.66	480	No
110	F	61	180	45	1.23	0.73	3171	No

111	F	64	150	31	0.49	0.64	6160	No
112	F	62	119	36	5.63	15.12	1229	No
113	F	48	120	53	5.63	15.12	1131	No
114	F	65	218	40	4.83	2.66	1171	No
115	F	69	165	42	4.83	2.66	6109	No
116	F	62	118	50	4.83	2.66	2783	No
117	F	62	159	53	4.83	2.66	3829	No
118	F	67	127	44	4.83	2.66	474	No
119	F	63	178	30	4.83	2.66	217	No
120	F	61	143	45	4.83	2.66	6109	No
121	F	67	280	31	4.83	2.66	3417	No
122	F	61.5	116	54	4.83	2.66	6109	No
123	F	60	138	29	3.94	3.69	1148	No
124	F	63	116	28	2.89	1.99	8833	No
125	F	64	130	37	4.42	1.89	1197	No
126	F	63	210	39	20.52	1.62	1522	No
127	F	65	140	39	20.52	1.62	823	Yes
128	F	72	180	37	20.52	1.62	9514	No
129	F	66	140	26	13.84	1.40	216	No
130	F	65	160	29	4.83	2.66	474	No
131	F	67	137	30	0.60	0.53	1206	No
132	F	64	128	44	0.60	0.53	4103	No
133	F	67	190	33	0.71	0.57	2297	No
134	F	66	135	39	5.50	2.41	2520	No
135	F	62	120	30	5.50	2.41	3914	No
136	F	66	120	36	5.50	2.41	6189	No
137	F	64	140	54	5.50	2.41	4017	No
138	F	69	168	23	0.65	0.69	6600	No

139	F	66	158	41	2.16	2.12	5217	Yes
140	F	64	120	36	2.20	2.23	257	No
141	F	76	240	41	1.13	0.92	743	No
142	F	64	200	45	0.57	0.46	6446	No
143	F	63.25	150	36	0.81	0.93	5354	No
144	M	68	220	27	0.28	0.16	3780	No
145	M	69	235	29	4.56	2.86	3177	No
146	M	72	185	31	4.56	2.86	2674	No
147	M	68	155	38	4.56	2.86	3846	Yes
148	M	65	218	32	5.44	2.27	6411	No
149	M	71	182	35	5.44	2.27	3846	No
150	M	69	167	38	5.44	2.27	4063	No
151	M	75	240	28	5.44	2.27	2354	No
152	M	74	195	40	6.02	0.41	658	No
153	M	70	178	40	6.02	0.41	1439	No
154	M	72	210	28	1.81	1.92	5697	No
156	M	65	185	33	1.83	0.98	6217	No
157	M	70	165	48	1.56	0.92	789	No
158	M	67	190	56	1.56	0.92	1800	No
159	M	71	240	56	7.54	5.80	6303	No
160	M	68	223	66	1.14	0.89	2417	No
161	M	73	218	43	3.93	2.67	6480	No
162	M	68	203	44	1.41	0.67	1371	No
163	M	70	175	42	0.61	0.51	2211	No
164	M	66	147	39	0.61	0.51	6589	No
165	M	70	270	54	0.76	0.56	3589	No
166	M	66	200	65	0.76	0.57	1234	No
167	M	71	160	24	0.76	0.57	5051	No

168	M	72	160	28	0.76	0.57	5154	No
169	M	70	195	50	0.76	0.57	5160	No
170	M	71	150	27	0.76	0.57	1360	No
171	M	71	280	40	0.76	0.57	1360	No
172	M	70	170	45	0.76	0.57	1960	No
173	M	70	200	36	0.76	0.57	0	No
174	M	67	135	25	2.93	1.18	3103	No
175	M	60	140	30	2.93	1.18	3377	No
176	M	69	147	24	2.93	1.18	1234	No
177	M	73	210	29	2.93	1.18	5149	No
178	M	67	135	30	2.93	1.18	674	No
179	M	66	155	42	2.93	1.18	2371	No
180	M	67	145	49	1.02	1.26	954	No
181	M	70	185	42	1.02	1.26	4291	No
182	M	72	186	43	1.02	1.26	1623	No
183	M	64	140	28	1.02	1.26	1766	No
184	M	74	230	36	1.02	1.26	954	No
185	M	71	205	44	1.02	1.26	474	No
186	M	73	146	46	1.02	1.26	3520	No
187	M	74	270	37	1.02	1.26	1423	No
188	M	71	180	34	1.02	1.26	1983	No
189	M	70	220	44	1.02	1.26	1640	No
190	M	65	280	36	1.02	1.26	537	No
191	M	71	165	42	1.02	1.26	406	No
192	M	71	196	24	2.21	0.48	2200	No
193	M	70	160	44	3.04	1.03	2200	No
194	M	73	172	40	2.26	0.49	2200	No
195	M	74	225	35	1.02	0.78	1114	No

280	M	73	160	45	2.32	1.39	1640	No
281	M	71	200	26	2.32	1.39	0	No
282	M	72	205	30	2.32	1.39	2703	Yes
283	M	70	175	24	2.32	1.39	3623	No
284	M	67	175	32	2.32	1.39	1200	No
285	M	71.5	185	26	2.32	1.39	1349	No
286	M	73	265	31	2.32	1.39	0	No
287	M	69	145	23	1.53	1.75	2537	No
288	M	73	185	20	2.78	2.46	2051	No
289	M	72	177	22	2.98	2.15	3080	No
290	M	69	180	48	2.98	2.15	703	Yes
291	M	68	155	21	8.89	1.59	1536	No
292	M	72	215	30	8.89	1.59	1736	No
293	M	68	160	21	8.89	1.59	1736	No
294	M	65	170	39	1.63	1.69	1207	No
295	M	71	176	22	1.64	1.69	3200	No
296	M	71	215	40	1.29	1.11	1043	No
297	M	70	195	36	0.75	0.74	1783	No
298	M	67	140	27	0.75	0.74	1794	No
299	M	67	170	50	0.75	0.74	2234	No
300	M	71	165	38	0.75	0.74	1069	No
301	M	73	165	44	1.27	1.09	2223	No
302	M	62	145	47	1.27	1.09	1749	No
303	M	69	225	36	1.31	1.14	1503	No
304	M	69	185	50	1.27	1.09	229	No
305	M	71	185	44	1.36	1.12	2229	No
306	M	73	140	48	1.36	1.12	2309	No
307	M	65	120	47	1.58	1.21	1743	No

308	M	68	175	47	1.58	1.21	1834	No
309	M	76	214	39	1.58	1.21	1840	No
310	M	68	180	61	1.58	1.21	1754	No
311	M	68	165	29	1.58	1.21	2217	No
312	M	70	160	28	1.58	1.21	1034	No
313	M	70	155	39	1.58	1.21	1331	No
314	M	70	145	21	1.58	1.21	2223	No
315	M	72	170	23	1.58	1.21	1749	No
316	M	65	130	55	1.58	1.21	1417	No
317	M	60	170	21	1.58	1.21	1771	No
318	M	60	170	22	1.58	1.21	623	No
319	M	76	175	.	1.58	1.21	1663	No
320	M	66	190	43	5.38	2.71	1714	No
321	M	66	180	40	5.38	2.71	2086	No
322	M	70	150	49	2.84	1.59	2086	No
323	M	60	160	39	2.84	1.59	2086	No
324	M	64	246	35	2.84	1.59	2086	No
325	M	72	206	31	2.04	1.32	1937	Yes
326	M	70	230	36	2.04	1.32	1709	No
327	M	71	190	39	3.61	1.64	514	No
328	M	68	290	45	4.71	1.96	2269	No
329	M	74	265	52	1.30	1.14	246	No
330	M	68	195	29	1.30	1.14	1497	Yes
331	M	72	200	25	1.30	1.14	1463	No
332	M	68.5	115	63	1.30	1.14	1554	No
333	M	74	211	27	1.30	1.14	691	No
334	M	66	154	32	1.30	1.14	314	No
335	M	76	165	35	1.93	1.88	1937	No

336	M	63	145	44	1.93	1.88	2023	No
337	M	71	163	28	1.93	1.88	1920	No
338	M	67	200	24	1.93	1.88	1926	No
339	M	72	191	30	1.93	1.88	1554	No
340	M	71	251	28	10.11	4.90	1606	No
341	M	72	140	25	10.11	4.90	1920	No
342	M	70	215	30	4.67	2.03	1589	No
343	M	71	160	29	4.67	2.03	1486	No
344	M	71	220	41	4.67	2.03	920	No
345	M	117	225	47	4.67	2.03	783	No
346	M	72	215	36	4.67	2.03	2023	No
347	M	67	160	30	4.67	2.03	1949	No
348	M	71	220	35	4.67	2.03	2029	No
349	M	72	190	39	4.67	2.03	1463	No
350	M	70	155	56	3.88	2.37	926	No
351	M	68	275	37	3.88	2.37	834	No
352	M	64	250	43	3.88	2.37	360	No
353	M	68	150	26	3.88	2.37	1297	No
354	M	73	142	28	3.88	2.37	829	No
355	M	68	170	44	4.18	2.24	1383	No
356	M	74	285	25	4.18	2.24	1331	No
357	M	69	240	36	4.18	2.24	840	No
358	M	74	225	41	4.18	2.24	840	No
359	M	79	235	43	4.18	2.24	1383	No
360	M	71	170	39	4.18	2.24	823	No
361	M	71	230	23	4.18	2.24	846	No
362	M	71	180	30	6.38	3.49	1280	No
363	M	74	190	34	6.38	3.49	823	No

364	M	70.5	175	45	6.38	3.49	926	No
365	M	68	170	38	6.38	3.49	480	No
366	M	76	230	21	6.38	3.49	1303	No
367	M	72	300	34	1.28	1.06	651	No
368	M	74	185	38	1.28	1.06	1383	No
369	M	71	190	37	1.28	1.06	1280	No
370	M	71	180	50	1.28	1.06	743	No
371	M	73	220	26	1.28	1.06	891	No
372	M	76	300	43	1.28	1.06	1297	No
373	M	69	162	44	3.89	1.78	1234	No
374	M	69	185	56	3.89	1.78	760	No
375	M	67	160	43	3.89	1.78	811	No
376	M	72	305	36	3.89	1.78	1320	No
377	M	73	215	34	3.89	1.78	1246	No
378	M	67	180	40	3.89	1.78	1320	No
379	M	76	230	28	3.89	1.78	1320	No
380	M	68	150	36	3.89	1.78	760	No
381	M	73	210	51	3.89	1.78	1326	No
382	M	75	245	45	3.89	1.78	1303	No
383	M	70	200	43	3.89	1.78	760	No
384	M	73	175	41	3.89	1.78	760	No
385	M	71	200	36	5.09	3.49	1320	No
386	M	68	255	34	5.09	3.49	1234	No
387	M	67	170	34	5.09	3.49	880	No
388	M	69	170	25	5.09	3.49	211	No
389	M	66	160	25	3.18	1.90	1240	No
390	M	71	160	24	3.18	1.90	777	No
391	M	74	250	39	3.18	1.90	880	No

392	M	72	180	31	3.18	1.90	760	No
393	M	71	220	39	10.23	5.67	126	No
394	M	77	215	29	10.23	5.67	0	No
395	M	74	205	49	10.23	5.67	0	No
396	M	70	185	32	10.23	5.67	0	No
397	M	67	153	48	10.23	5.67	0	No
398	M	73	205	30	10.23	5.67	0	No
399	M	66	170	26	10.23	5.67	0	No
400	M	69	165	28	10.23	5.67	0	No
401	M	69	200	53	10.23	5.67	120	No
402	M	71	190	33	10.23	5.67	135	No
403	M	70	160	.	10.23	5.67	126	No
404	M	68	177	.	3.36	2.52	0	No
405	M	66	160	20	3.36	2.52	321	No
406	M	70	145	38	3.36	2.52	0	No
407	M	66	190	29	3.36	2.52	135	No
408	M	68	160	23	3.36	2.52	135	No
409	M	67	190	40	6.15	4.28	2263	No
410	M	71	150	25	6.15	4.28	1549	No
411	M	68	215	26	6.64	2.72	0	No
412	M	70	150	42	6.64	2.72	0	No
413	M	67	223	40	6.64	2.72	141	No
414	M	73	215	29	6.64	2.72	141	No
415	M	73	196	38	6.64	2.72	0	No
416	M	73	195	33	6.64	2.72	0	No
417	M	70	198	59	6.64	2.72	0	No
418	M	67	240	36	1.85	1.30	1377	No
419	M	66	140	25	1.85	1.30	810	No

420	M	70	165	29	1.85	1.30	154	No
421	M	70	163	24	1.85	1.30	154	No
422	M	69	131	27	1.85	1.30	137	No
423	M	69	130	23	1.85	1.30	154	No
424	M	74	200	30	1.85	1.30	0	No
425	M	67	230	25	1.85	1.30	0	No
426	M	65	245	29	1.85	1.30	148	No
427	M	71	175	44	1.85	1.30	154	No
428	M	70	195	34	1.85	1.30	148	No
429	M	70	195	44	1.85	1.30	148	No
430	M	67	165	36	1.85	1.30	148	No
431	M	72	170	33	1.14	1.03	91	No
432	M	71	160	35	1.14	1.03	0	No
433	M	68	185	39	1.14	1.03	0	No
434	M	69	180	52	1.14	1.03	91	No
435	M	70	195	48	1.14	1.03	91	No
436	M	75	190	26	1.14	1.03	0	No
437	M	68	154	25	1.14	1.03	91	No
438	M	73	185	21	4.26	1.95	0	No
439	M	70	275	33	4.26	1.95	91	No
440	M	71	190	23	4.26	1.95	91	No
441	M	68	180	20	4.26	1.95	0	No
442	M	66	170	38	4.26	1.95	0	No
443	M	71	145	38	4.26	1.95	0	No
444		.	.	.	4.26	1.95	91	No
445		.	.	.	4.04	2.00	91	No
446		.	.	.	4.04	2.00	91	No
447		.	.	.	4.04	2.00	0	No

448	.	.	.	4.20	1.95	0	No
449	.	.	.	4.20	1.95	40	No

196	M	72	175	27	1.02	0.78	4809	No
197	M	67	200	29	2.31	2.30	2440	No
198	M	68	205	39	2.31	2.30	2440	No
199	M	68	210	.	2.31	2.30	5714	No
200	M	71	160	45	2.31	2.30	2429	No
201	M	72	213	43	2.31	2.30	680	No
202	M	73	215	36	2.36	0.61	783	No
203	M	72	218	41	2.36	0.61	1531	No
204	M	74	227	35	2.36	0.61	5149	No
205	M	73	140	32	2.36	0.61	309	No
206	M	72	174	27	2.36	0.61	3737	No
207	M	72	185	27	39.05	17.87	114	No
208	M	70	120	35	39.05	17.87	629	Yes
209	M	74	160	42	39.05	17.87	331	No
210	M	81	260	31	39.05	17.87	629	No
211	M	72	180	32	1.24	1.35	5149	No
212	M	71	215	28	1.24	1.35	2949	No
213	M	75	165	30	1.24	1.35	5149	No
214	M	69	150	39	1.61	0.97	1337	No
215	M	71	280	62	1.61	0.97	1406	No
216	M	75	176	22	1.61	0.97	1794	No
217	M	69	145	25	1.61	0.97	3309	No
218	M	67	160	43	1.61	0.97	3177	No
219	M	68	205	40	1.61	0.97	4434	No
220	M	71	122	26	1.61	0.97	851	No
221	M	68	183	46	2.17	1.65	1506	No
222	M	66	174	28	2.17	1.65	2908	No
223	M	64	140	49	2.17	1.65	4232	No

224	M	65	200	37	2.17	1.65	516	No
225	M	69	185	49	2.17	1.65	1530	No
226	M	71	225	30	2.17	1.65	1396	No
227	M	61	168	43	2.17	1.65	1409	No
228	M	69	200	38	2.17	1.65	3200	No
229	M	67	150	27	1.43	0.65	3023	No
230	M	66	180	28	1.43	0.65	3023	No
231	M	67	170	30	0.92	0.58	1377	No
232	M	67	165	39	1.43	0.65	1640	No
233	M	65	145	24	1.43	0.65	349	No
234	M	67	150	28	17.21	8.95	149	Yes
235	M	67	145	25	17.21	8.95	4423	No
236	M	67	153	28	17.21	8.95	4423	No
237	M	66	165	30	17.21	8.95	2371	No
238	M	68	150	39	17.21	8.95	457	No
239	M	70	160	56	17.21	8.95	2446	No
240	M	72	200	48	17.21	8.95	3331	No
241	M	74	195	30	17.21	8.95	3811	No
242	M	67	160	37	17.21	8.95	4423	No
243	M	71	160	36	2.22	1.66	1314	No
244	M	66	175	38	11.64	2.85	971	No
245	M	69	172	62	11.64	2.85	4455	No
246	M	68	174	52	11.64	2.85	1569	No
247	M	71	185	57	11.64	2.85	572	No
248	M	73	150	35	4.54	2.54	4044	No
249	M	71	165	43	4.54	2.54	19	No
250	M	66	182	62	1.54	1.32	2029	No
251	M	68	308	33	1.54	1.32	1657	No

252	M	72	190	22	1.46	1.26	2497	No
253	M	67	215	24	1.46	1.26	4074	No
254	M	72	195	23	1.46	1.26	897	No
255	M	66	160	27	1.46	1.26	600	No
256	M	72	185	39	1.46	1.26	194	No
257	M	69	220	23	1.46	1.26	354	No
258	M	66	167	35	3.03	1.97	0	No
259	M	73	224	57	3.03	1.97	3594	No
260	M	64	.	45	2.31	2.18	2994	No
261	M	68	188	52	8.42	2.87	2697	No
262	M	72	165	38	8.42	2.87	354	No
263	M	65	151	33	8.42	2.87	2423	No
264	M	68	170	53	8.42	2.87	3954	No
265	M	69	204	39	0.64	0.55	3480	No
266	M	71	185	49	1.23	0.65	491	No
267	M	70	160	42	9.98	5.86	3446	No
268	M	75	195	35	3.10	1.75	3949	No
269	M	68	140	25	9.98	5.86	3611	No
270	M	70	170	23	9.98	5.86	4074	No
271	M	68	166	30	1.04	1.02	486	No
272	M	69	183	53	1.04	1.02	1857	No
273	M	72	180	26	2.21	1.65	1840	No
274	M	65	130	31	3.60	1.32	520	No
275	M	69	165	55	3.60	1.32	1246	No
276	M	70	195	36	1.76	1.41	3949	No
277	M	70.5	210	29	2.14	1.24	2006	No
278	M	66	173	33	2.22	1.66	4114	No
279	M	74.5	235	27	10.02	8.09	3034	No