2. PROCEDURES FOR ANALYZING LIFTING JOBS

This section describes the procedures that should be followed to correctly assess the physical demands of a manual lifting job.

2.1. Options

Prior to the assessment, the analyst must determine (1) if the job should be analyzed as a single-task or multi-task manual lifting job, and (2) if significant control is required at the destination of the lift.

A single-task manual lifting job is defined as a lifting job in which the task variables do not significantly vary from task to task, or only one task is of interest (e.g., worst case analysis). This may be the case if the effects of the other tasks on strength, localized muscle fatigue, or whole-body fatigue do not differ significantly from the worst case task.

On the other hand, multi-task manual lifting jobs, which are defined as jobs in which there are significant differences in task variables between tasks, are more difficult to analyze because each task must be analyzed separately. Therefore, a specialized procedure is used to analyze multi-task manual lifting jobs.

2.1.1. Rationale for Determining Significant Control

When significant control of an object is required at the destination of a lift, the worker must apply a significant upward force to decelerate the object. Depending upon the velocity of the lift, this deceleration force may be as great as the force required to lift the object at the origin. Therefore, to insure that the appropriate RWL is computed for a lift that requires significant control at the destination, the RWL is calculated at ***both*** the origin and the destination of the lift, and the lower of the two values is used to assess the overall lift. The latter procedure is required if (1) the worker has to re-grasp the load near the destination of the lift, (2) the worker has to momentarily hold the object at the destination, or (3) the worker has to position or guide the load at the destination. The purpose of calculating the RWL at both the origin and destination of the lift is to identify the most stressful location of the lift.

2.1.2. Rationale for Multi-task Analysis Procedure

The initial recommendation for analyzing the physical demands of multi-task manual lifting jobs was included in the NIOSH WPG (1981). The procedure was designed to determine the collective effects of all the tasks. The procedure included: (1) determining a frequency-weighted average for each task variable; (2) determining each of the four multipliers, the AL and the MPL, using the frequency-weighted average variables; and, (3) comparing the frequency-weighted average weight with the AL and MPL. The averaging approach, however, can mask the effects of hazardous task variables, resulting in an underestimation of the lifting hazard (Waters, 1991). For example, consider a multi-task job consisting of two separate tasks, each with a frequency of 1 lift/minute and vertical heights (V) of 0 and 60 inches. Although both tasks considered individually would have large penalties for the vertical height factor, when combined in this manner the frequency-weighted (average) V is 30 inches, which cancels the penalty for vertical height, resulting in no reduction in the recommended weight limit. Because of the potential inaccuracies that can occur when task variables are averaged for multi-task assessments, a new multi-task method was developed. The method is described on page 43.

The new method is based on the following assumptions:

1. That performing multiple lifting tasks would increase the physical or metabolic load, and that this increased load should be reflected in a reduced recommended weight limit and increased Lifting Index.

2. That an increase in the Lifting Index depends upon the characteristics of the additional lifting task.

3. That the increase in the Lifting Index due to the addition of one or more tasks is independent of the Lifting Index of any of the preceding tasks (i.e., Lifting Indices from tasks already performed).

Although the procedure does not consider the potential interaction between individual lifting tasks, we believe this effect is minimal.

The new method is based on the concept that the Composite Lifting Index (CLI), which represents the collective demands of the job, is equal to the sum of the largest Single Task Lifting Index (STLI) and the incremental increases in the CLI as each subsequent task is added. The incremental increase in the CLI for a specific task is defined as the difference between the Lifting Index for that task at the cumulative frequency and the Lifting Index for that task at its actual frequency. For example, consider two identical tasks (A and B), each with a lifting frequency of 1 lift/minute.

Using the new concept:

$$CLI = LI_{A,1} + (LI_{B,2} - LI_{B,1})$$

In these equations, the numeric part of the subscript represents the frequency, such that $LI_{B,2}$ indicates the LI value for Task B at a frequency of 2 lifts/minute and $LI_{B,1}$ indicates the LI value for Task B at a frequency of 1 lift/minute.

Since task A and B are identical, $LI_{A,1}$ and $LI_{B,1}$ cancel out and $CLI = LI_{B,2}$. As expected, the CLI for the job is equivalent to the LI value for the simple task being performed at a rate of 2 times/minute. Now, if the two tasks are different, then

$$CLI = LI_{A,1} + (LI_{B,2} - LI_{B,1})$$

In this case, $LI_{A,1}$ and $LI_{B,1}$ do not cancel each other out. The CLI is equal to the sum of $LI_{A,1}$, which refers to the demand of Task A, and the increment of demand for Task B, with the increment being equal to the increase in demand when the frequency for Task B is increased from 1 lift/minute (corresponding to the frequency of Task A) to a rate of 2 lifts/minute (corresponding to the sum of the frequencies of Task A and B). Thus, as each additional task is added, the **CLI** is increased appropriately.

While the new method has not been validated at the workplace, this multi-task version will minimize errors due to averaging; and thereby, provide a more accurate method for estimating the combined effects of multi-tasked lifting jobs than was provided in the NIOSH WPG (1981).

Many of the lifting jobs in the workplace have multiple lifting activities, and therefore could be analyzed as either a single or a multi-task lifting job. When detailed information is needed, however, to specify engineering modifications, then the multi-task approach should be used. On the other hand, the multi-task procedure is more complicated than the single-task procedure, and requires a greater understanding of assessment terminology and mathematical concepts. Therefore, the decision to use the single or multi-task approach should be based on: (1) the need for detailed information about all facets of the multi-task lifting job, (2) the need for accuracy and completeness of data in performing the analysis, and (3) the analyst's level of understanding of the assessment procedures.

To perform a lifting analysis using the revised lifting equation, two steps are undertaken: (1) data is collected at the worksite and (2) the Recommended Weight Limit and Lifting Index values are computed using the single-task or multi-task analysis procedure. These two steps are described in the following sections.

2.2. Collect Data (Step 1)

The relevant task variables must be carefully measured and clearly recorded in a concise format. The Job Analysis Worksheet for either a single-task analysis (Figure 3) or a multi-task analysis (Figure 4) provides a simple form for recording the task variables and the data needed to calculate the RWL and the LI values. A thorough job analysis is required to identify and catalog each independent lifting task that comprises the worker's complete job. For multi-task jobs, data must be collected for each individual task. The data needed for each task include the following:

1. **Weight of the object lifted.** Determine the load weight (L) of the object (if necessary, use a scale). If the weight of the load varies from lift to lift, record the average and maximum weights.

2. **Horizontal and vertical locations of the hands with respect to the mid-point between the ankles.** Measure the horizontal location (H) and vertical location (V) of the hands at both the origin and destination.

3. **Angle of asymmetry.** Determine the angle of asymmetry (A) at the origin and destination of the lift.

4. **Frequency of lift.** Determine the average lifting frequency rate (F), in lifts/min, periodically throughout the work session (average over at least a 15-minute period). If the lifting frequency varies from session to session by more than two lifts/min, each work session should be analyzed as a separate task. The duration category, however, must be based on the overall work pattern of the entire workshift.

5. **Lifting duration.** Determine the total time engaged in continuous lifting and the schedule of recovery allowances (i.e., light work assignments) for each lifting task. Compute the recovery-time to work-time ratio to classify the job for work duration (i.e., Short, Moderate, or Long).

JOB ANALYSIS WORKSHEET

DEPARTMENT ____________________

JOB TITLE ____________________

ANALYST'S NAME ____________________

DATE ____________________

JOB DESCRIPTION

____

____

____

STEP 1. Measure and record task variables

Object Weight (lbs)		Hand Location (in) Origin		Hand Location (in) Dest.		Vertical Distance (in)	Asymmetric Angle (degrees) Origin	Asymmetric Angle (degrees) Destination	Frequency Rate lifts/min	Duration (HRS)	Object Coupling
L (AVG.)	L (Max.)	H	V	H	V	D	A	A	F		C

STEP 2. Determine the multipliers and compute the RWL's

RWL = LC × HM × VM × DM × AM × FM × CM

ORIGIN RWL = [51] × [ ] × [ ] × [ ] × [ ] × [ ] × [ ] = [ ] Lbs

DESTINATION RWL = [51] × [ ] × [ ] × [ ] × [ ] × [ ] × [ ] = [ ] Lbs

STEP 3. Compute the LIFTING INDEX

ORIGIN LIFTING INDEX = OBJECT WEIGHT (L) / RWL = ______ = [ ]

DESTINATION LIFTING INDEX = OBJECT WEIGHT (L) / RWL = ______ = [ ]

Figure 3: Single Task Job Analysis Worksheet

MULTI-TASK JOB ANALYSIS WORKSHEET

DEPARTMENT ____________________ JOB DESCRIPTION

JOB TITLE ____________________ ____________________

ANALYST'S NAME ____________________ ____________________

DATE ____________________ ____________________

STEP 1. Measure and Record Task Variable Data

Task No.	Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetry Angle (degs)		Frequency Rate lifts/min	Duration Hrs	Coupling
			Origin		Dest.			Origin	Dest.			
	L (Avg.)	L (Max.)	H	V	H	V	D	A	A	F		C
______												
______												
______												
______												
______												

STEP 2. Compute multipliers and FIRWL, STRWL, FILI, and STLI for Each Task

Task No.	LC x	HM x	VM x	DM x	AM x	CM	FIRWL x	FM	STRWL	FILI = L/FIRWL	STLI = L/STRWL	New Task No.	F
	51												
	51												
	51												
	51												
	51												

STEP 3. Compute the Composite Lifting Index for the Job (After renumbering tasks)

CLI =	$STLI_1$ +	Δ $FILI_2$ +	Δ $FILI_3$ +	Δ $FILI_4$ +	Δ $FILI_5$	
		$FILI_2(1/FM_{1,2} - 1/FM_1)$	$FILI_3(1/FM_{1,2,3} - 1/FM_{1,2})$	$FILI_4(1/FM_{1,2,3,4} - 1/FM_{1,2,3})$	$FILI_5(1/FM_{1,2,3,4,5} - 1/FM_{1,2,3,4})$	
CLI =						

Figure 4: MULTI-TASK JOB ANALYSIS WORKSHEET

6. **Coupling type**. Classify the hand-to-container coupling based on Table 6

2.3. Single-Task Assessment (Step 2)

Calculate the RWL at the origin for each lift. For lifting tasks that require significant control at the destination, calculate the RWL at **both** the origin and the destination of the lift. The latter procedure is required if (1) the worker has to re-grasp the load near the destination of the lift, (2) the worker has to momentarily hold the object at the destination, or (3) the worker has to position or guide the load at the destination. The purpose of calculating the RWL at both the origin and destination of the lift is to identify the most stressful location of the lift. Therefore, the lower of the RWL values at the origin or destination should be used to compute the Lifting Index for the task, since this value would represent the limiting set of conditions.

The assessment is completed on the single-task worksheet by determining the lifting index (LI) for the task of interest. This is accomplished by comparing the actual weight of the load (L) lifted with the RWL value obtained from the lifting equation.

2.4. Multi-Task Procedure

1. Compute the Frequency-Independent Recommended Weight Limit (FIRWL) and Single-Task Recommended Weight Limit (STRWL) for each task.

2. Compute the Frequency-Independent Lifting Index (FILI) and Single-Task Lifting Index (STLI) for each task.

3. Compute the Composite Lifting Index (CLI) for the overall job.

2.4.1. Compute the FIRWL for Each Task

Compute the Frequency Independent Weight Limit (FIRWL) value for each task by using the respective task variables and setting the Frequency Multiplier to a value of 1.0. The FIRWL for each task reflects the compressive force and muscle strength demands for a single repetition of that task. If significant control is required at the destination for any individual task, the FIRWL must be computed at both the origin and the destination of the lift, as described above for a single-task analysis.

2.4.2. Compute the STRWL for Each Task

Compute the Single-Task Recommended Weight Limit (STRWL) for each task by multiplying its FIRWL by its appropriate Frequency Multiplier (FM). The STRWL for a task reflects the overall demands of that task, assuming it was the only task being performed. Note, this value does not reflect the overall demands of the task when the other tasks are considered. Nevertheless, this value is helpful in determining the extent of excessive physical stress for an individual task.

2.4.3. Compute the FILI for Each Task

Compute the Frequency-Independent Lifting Index (FILI) for each task by dividing the ***maximum*** load weight (L) for that task by the respective FIRWL. The maximum weight is used to compute the FILI because the maximum weight determines the maximum biomechanical loads to which the body will be exposed, regardless of the frequency of occurrence.. Thus, the FILI can identify individual tasks with potential strength problems for infrequent lifts. If any of the FILI values exceed a value of 1.0, then ergonomic changes may be needed to decrease the strength demands.

2.4.4. Compute the STLI for Each Task

Compute the Single-Task Lifting Index (STLI) for each task by dividing the ***average*** load weight (L) for that task by the respective STRWL. The average weight is used to compute the STLI because the average weight provides a better representation of the metabolic demands, which are distributed across the tasks, rather than dependent on individual tasks. The STLI can be used to identify individual tasks with excessive physical demands (i.e., tasks that would result in fatigue). The STLI values do not indicate the relative stress of the individual tasks in the context of the whole job, but the STLI value can be used to prioritize the individual tasks according to the magnitude of their physical stress. Thus, if any of the STLI values exceed a value of 1.0, then ergonomic changes may be needed to decrease the overall physical demands of the task. Note, it may be possible to have a job in which all of the individual tasks have a STLI less than 1.0 and still be physically demanding due to the combined demands of the tasks. In cases where the FILI exceeds the STLI for any task, the maximum weights may represent a significant problem and careful evaluation is necessary.

2.4.5. Compute the CLI for the Job

The assessment is completed on the multi-task worksheet by determining the Composite Lifting Index (CLI) for the overall job. The CLI is computed as follows:

1. The tasks are renumbered in order of decreasing physical stress, beginning with the task with the greatest STLI down to the task with the smallest STLI. The tasks are renumbered in this way so that the more difficult tasks are considered first.

2. The CLI for the job is then computed according to the following formula:

$$CLI = STLI_1 + \sum \Delta LI$$

Where:

$$\sum \Delta LI = (FILI_2 \times (\frac{1}{FM_{1,2}} - \frac{1}{FM_1}))$$

$$+(FILI_3 \times (\frac{1}{FM_{1,2,3}} - \frac{1}{FM_{1,2}}))$$

$$+ (FILI_4 \times (\frac{1}{FM_{1,2,3,4}} - \frac{1}{FM_{1,2,3}}))$$

.

.

.

$$+(FILI_n \times (\frac{1}{FM_{1,2,3,4,\ldots,n}} - \frac{1}{FM_{1,2,3,\ldots,(n-1)}}))$$

Note, that (1) the numbers in the subscripts refer to the new task numbers; and, (2) the FM values are determined from Table 5, based on the sum of the frequencies for the tasks listed in the subscripts.

The following example is provided to demonstrate this step of the multi-task procedure. Assume that an analysis of a typical three-task job provided the following results:

Task Number	1	2	3
Load Weight (L)	30	20	10
Task Frequency (F)	1	2	4
FIRWL	20	20	15
FM	.94	.91	.84
STRWL	18.8	18.2	12.6
FILI	1.5	1.0	.67
STLI	1.6	1.1	.8
New Task Number	1	2	3

To compute the Composite Lifting Index (CLI) for this job, the tasks are renumbered in order of decreasing physical stress, beginning with the task with the greatest STLI down to the task with the smallest STLI. In this case, the task numbers do not change. Next, the CLI is computed according to the formula shown on the previous page. The task with the greatest CLI is Task 1 (STLI = 1.6). The sum of the frequencies for Tasks 1 and 2 is 1+2 or 3, and the sum of the frequencies for Tasks 1, 2 and 3 is 1+2+4 or 7. Then, from Table 5, FM_1 is .94, $FM_{1,2}$ is .88, and $FM_{1,2,3}$ is .70. Finally, the CLI = 1.6 + 1.0(1/.88 - 1/.94)+.67(1/.70 - 1/.88) = 1.6 + .07 + .20 = 1.9. Note that the FM values were based on the sum of the frequencies for the subscripts, the vertical height, and the duration of lifting.