ABB	SA-S-304-01-03 Using advanced ergonomics risk assessment tools			
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STEP BY STEP FOR TASK ANALYSIS USING ADVANCED ERGONOMICS TOOLS

Common steps for all ergonomics tools

- **Recognition**

  The objective of this point is to be familiar with the job that is going to be assessed. During this phase, the ergonomist must define the task to be evaluated carefully and observe every detail that is part of the activity; tools, machinery, materials, and equipment use, as well as measure cycle time.

- **Video recording**

  Once familiar with the activity to be evaluated, a video recording of the activity must be completed; it is recommended that recording time contains sufficient work cycles to obtain a reliable analysis. As a minimum, three work cycles for repetitive tasks, and 5 to 10 minutes for non-repetitive tasks must be recorded. The video should include recording from both left and right view profiles of the worker, making sure the entire body is included and observable; recording must also be continuous, without interruptions.

- **Task description**

  This is a very short description of the major purpose of the job. This description emphasizes what the employee is doing instead of the work methods used to perform the job. Example: Operators carry an instrumental panel from the storage rack and install it into the machine. After completing the necessary electrical connections, the instrument panel is secured into position with a pneumatic nut-runner.

- **Subtasks separation**

  Once completed, recordings must be viewed and analyzed, repeating as often as necessary, until the ergonomist can list all subtasks performed by the observed worker. It is recommended to name the tasks and subtasks with short names or codes, which will allow for easy identification of what the worker is performing.

- **Calculation of total observation time**

  The total observation time is the time required by an average skilled operator, working at a normal pace, to perform a specified task using a prescribed method and includes appropriate allowances to allow the person to recover from fatigue and, where necessary, an additional allowance to cover contingent elements which may occur but have not been observed. The total observation time should be used to calculate acyclic tasks or tasks that do not repeat more than one time per shift.

Cycle time is the total time from the beginning to the end of your process, as defined by you and your customer. Cycle time includes process time, during which a unit is acted upon to bring it closer to an

output, and delay time, during which a unit of work is spent waiting to take the next action and should be used in cyclic activities.
The total observation time and cycle time could be collected in any unit of measurement; however, they must be converted into seconds to be used in the ergonomics tools.

- **Determine the single extortion time of non-neutral postures**

Describe the main non-neutral postures regarding the task, after determining the time of single extortion in seconds.

- **Determine the number of exertions during the observation time**

Count the number of exertions during the total observation time or the cycle time.

- **Determine production information**

Production information such as the speed of an assembly line (e.g. 40 units per hour) on machine-paced jobs or work standards (e.g. the standard or allowed time to produce one part) on unpaced jobs, is needed to estimate the number of work cycles performed per shift.
These data are important for the ergonomics job analysis because they are needed to estimate the repetitiveness of a job.

Specifics steps according to each ergonomics tool

1. Rodgers Muscle Fatigue Analysis

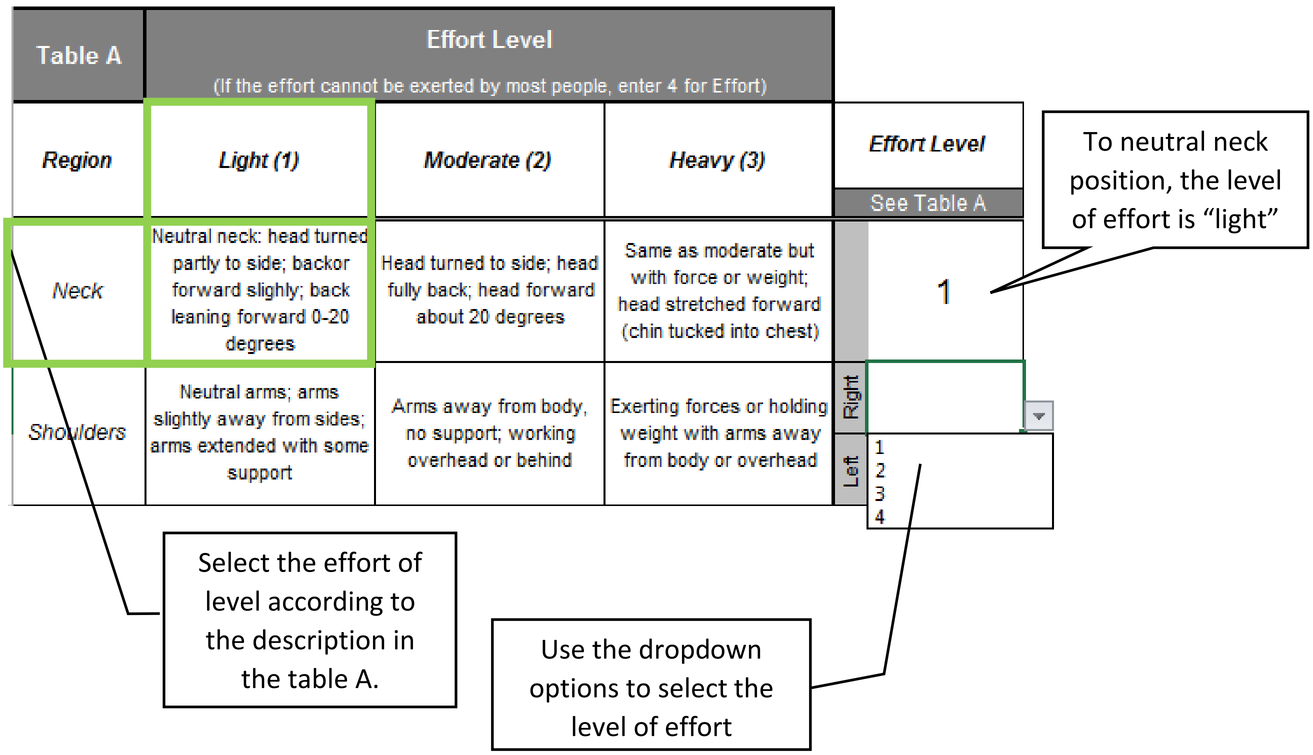
This method works best for evaluating production tasks having fewer than 12 to 15 repetitions per minute with the same muscle groups. It also can be used for studying some service and office jobs, but it will underestimate postural loads that are sustained continuously for more than 30 sec.
It is not appropriate for use if fatigue is not likely to occur on a task, e.g., performing an occasional heavy lift. Any task that is beyond the capacity of more than half of the potential workforce should be fixed based on that very high effort level. Fatigue should only be a consideration if the effort is initially within reasonable guidelines.

This method works best if all the muscle groups are rated for each task, not just the ones that appear to be most involved in the heavier work. Some of the less heavily loaded muscles may have a combination of holding time and frequency of use that makes them more vulnerable to fatigue than the muscles that may be involved in short, heavy efforts. Also, when improvements to the tasks are identified, it is wise to rerate the task and all the body parts again, because the proposed improvement may have shifted the load to another muscle group that now becomes the limiting one.
Below is the procedure for using this tool:

i.Determine effort intensity levels for each body part

- Use unedited videotape to study the task

- Ask workers to rate effort intensity using a psychophysical scale.
  - Define effort level from definitions.
  - Rate effort for right and left sides, if appropriate
  - If more than one level of effort is present, (e.g., moderate, and heavy), include both.



ii. Determine effort duration, in seconds, for each effort intensity for each body part

- Use a stopwatch to time the seconds of continuous effort at a given effort intensity before a different effort intensity or relaxation occurs.
- Example: the number of continuous effort duration is 15 seconds, which refers to the score number 2 (6 - 20 s). Use the dropdown options to select the continuous effort duration score.

Table A	Effort Level (If the effort cannot be exerted by most people, enter 4 for Effort)			Scores	
Region	*Light (1)*	*Moderate (2)*	*Heavy (3)*	*Effort Level* See Table A	*Cont. Effort Duration* See Table B
Neck	Neutral neck: head turned partly to side; backor forward slighly; back leaning forward 0-20 degrees	Head turned to side; head fully back; head forward about 20 degrees	Same as moderate but with force or weight; head stretched forward (chin tucked into chest)	1	2

Table B	Score = 1	Score = 2	Score = 3	Score = 4
Continuous Effort Duration	< 6 s	6 - 20 s	20 - 30 s	> 30 s
Effort Frequency	< 1 / min	1 - 5 / min	6 - 15 / min	> 15 / min

iii. Determine the frequency of efforts per minute at the same effort intensity for each body part

- Count the number of new efforts at a given effort intensity over 1 min; if the task is very variable, measure the frequency over 5 min and divide by 5 to get the efforts per minute.
- Use the same reference of continuous effort duration to reach the effort frequency score.
- In the example below the effort frequency is between 6 – 15/ min. The reached score is 3.

Table A	Effort Level (If the effort cannot be exerted by most people, enter 4 for Effort)			Scores		
Region	*Light (1)*	*Moderate (2)*	*Heavy (3)*	*Effort Level* See Table A	*Cont. Effort Duration* See Table B	*Effort Frequency*
Neck	Neutral neck: head turned partly to side; backor forward slighly; back leaning forward 0-20 degrees	Head turned to side; head fully back; head forward about 20 degrees	Same as moderate but with force or weight; head stretched forward (chin tucked into chest)	1	2	3

Table B	Score = 1	Score = 2	Score = 3	Score = 4
Continuous Effort Duration	< 6 s	6 - 20 s	20 - 30 s	> 30 s
Effort Frequency	< 1 / min	1 - 5 / min	6 - 15 / min	> 15 / min

iv. Using the three-number rating generated from steps 4 to 6 above, determine the score. Put it in the last column for each body part

- Use Table 12.2 to obtain the “priority for change” rating from the three-number rating based on effort intensity, effort duration, and effort frequency for each body part.
- The level of ergonomics risk will appear automatically in the overall priority column.

Table A	Effort Level (If the effort cannot be exerted by most people, enter 4 for Effort)			Scores			Overall Priority
Region	*Light (1)*	*Moderate (2)*	*Heavy (3)*	*Effort Level* See Table A	*Cont. Effort Duration* See Table B	*Effort Frequency*	
Neck	Neutral neck: head turned partly to side; backor forward slighly; back leaning forward 0-20 degrees	Head turned to side; head fully back; head forward about 20 degrees	Same as moderate but with force or weight; head stretched forward (chin tucked into chest)	1	2	3	Moderate

2. Strain Index

The strain index (SI) is a method of evaluating jobs to determine if they expose workers to an increased risk of developing musculoskeletal disorders of the distal upper extremity (DUE). The DUE is defined as the elbow, forearm, wrist, and hand. Musculoskeletal disorders of the DUE include specific diagnoses (e.g., epicondylitis, tendinitis, tendon entrapment at the wrist or finger, and carpal tunnel syndrome) and less specific symptomatic conditions related to the muscle-tendon units of the DUE.

The strain index uses six task variables to describe hand exertions:

a) **Intensity of exertion:** is an estimate of the force requirements of the task, reflecting the magnitude of muscular effort required to perform the task one time. The proposed methodology involves estimating the intensity of exertion using verbal descriptors, which estimate perceived exertion. The methodology relies on observers to rate the intensity of exertion.
It should be selected as a rating criterion according to the observation. Each rating criterion refers to a respective multiplier in the same line.

Risk Factor	Rating Criterion	Observation	Multiplier
Intensity of Exertion (Borg Scale - BS)	Light	Barely noticeable or relaxed effort (BS: 0-2)	1
	Somewhat Hard	Noticeable or definite effort (BS: 3)	3
	Hard	Obvious effort; Unchanged facial expression (BS: 4-5)	6
	Very Hard	Substantial effort; Changes expression (BS: 6-7)	9
	Near Maximal	Uses shoulder or trunk for force (BS: 8-10)	13

b) **Duration of exertion:** reflects the stresses related to how long an exertion is maintained. It is the percentage of time of a single exertion divided by the total observation time or cycle time.
Each rating criterion refers to a respective multiplier in the same line. The rating criterion is reached in part from the calculated duration of exertion (5).
The methodology to achieve the calculated duration of exertion will be presented in the next steps.

Risk Factor	Rating Criterion	Observation			Multiplier
Duration of Exertion (% of Cycle)	< 10%	Calculated Duration of Exertion (from inputs below)			0,5
	10-29%	User Inputs	Left	Right	1,0
	30-49%	Total observation time (sec.)		5760	1,5
	50-79%	Single exertion time (sec.)		120	2,0
	≥ 80%	Number of exertions during observation time		25	3,0
		Calculated Duration of Exertion (%)		52,1 %	

c) **Efforts per minute**: it is the number of exertions per minute and is measured by counting the number of exertions that occur during the total observation time.
Each rating criterion refers to a respective multiplier in the same line.
The efforts per minute will be calculated automatically.

Risk Factor	Rating Criterion	Observation			Multiplier
Efforts Per Minute	< 4	Calculated Efforts Per Minute (from inputs above)			0,5
	4 - 8		Left	Right	1,0
	9 - 14			0,26	1,5
	15 - 19				2,0
	≥ 20				3,0

d) **Hand/wrist posture:** postures refer to the anatomical position of the wrist or hand relative to the neutral position. An observer rates the postures qualitatively. Differences among multiple job analysts should be resolved by consensus.
It should be selected as a rating criterion according to the observation. Each rating criterion refers to a respective multiplier in the same line.

Risk Factor	Rating Criterion	Observation	Multiplier
Hand/Wrist Posture	Good	Near Neutral	1,0
	Fair	Non-Neutral	1,5
	Bad	Marked Deviation	2,0
	Very Bad	Near Extreme	3,0

e) **Speed of work (how fast)**: estimates the perceived pace of the task. It is subjectively estimated by a job analyst.
It should be selected as a rating criterion according to the observation. Each rating criterion refers to a respective multiplier in the same line.

Risk Factor	Rating Criterion	Observation	Multiplier
Speed of Work	Very Slow	Extremely relaxed pace	1,0
	Slow	Taking one's own time	1,0
	Fair	Normal speed of motion	1,0
	Fast	Rushed, but able to keep up	1,5
	Very Fast	Rushed and barely/unable to keep up	2,0

f) **Duration per day:** Reflects the total time that a task is performed per day. It is measured and expressed by hours.
It should be selected as a rating criterion according to total time the task is performed per day. Each rating criterion refers to a respective multiplier in the same line.

Risk Factor	Rating Criterion	Observation	Multiplier
Duration of Task Per Day (hours)	<1		0,25
	1 < 2		0,50
	2 < 4		0,75
	4 ≤ 8		1,00
	> 8		1,50

The strain index involves the direct measurement of duration of exertion, efforts per minute, and duration per day and the estimation or direct measurement of the intensity of exertion, hand/wrist posture, and speed of work. The values of these task variables represent descriptions of exposure (external physical stress). Translation of this information into dose and dosage (internal physical strain) is done by a set of linking functions that specify multiplier values for the values of the task variables. The strain index score is the product of these six multipliers.

Procedures to use the Strain Index worksheet

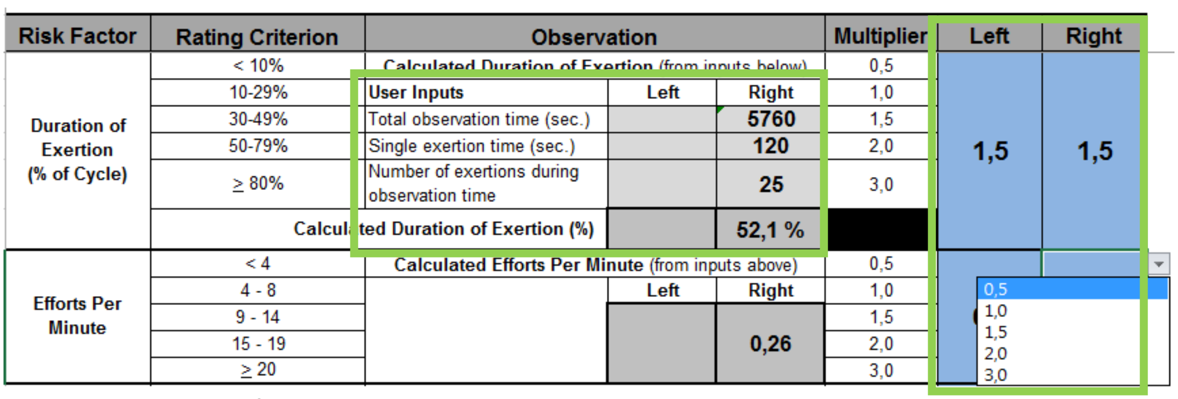
To analyze a job with the strain index, it is important to observe or videotape a representative sample of the job. It is easier to perform the analysis from a videotape. Strain index calculators have been developed by several individuals and organizations. The right and left sides are analyzed separately.
The higher score should be used to characterize the job as a whole. In terms of procedure, there the following steps:

1. Determine the total observation time or cycle time.
2. Collect data on the six task variables.
3. Assign ordinal ratings using the ratings table.
4. Determine multiplier values using the multiplier table.
5. Calculate the SI score (the product of the six multiplier values).
6. Interpret the result.

Data collection usually begins with the definition of the total observation time or job cycle time. The total observation time is the time required by an average skilled operator, working at a normal pace, to perform a specified task using a prescribed method and includes appropriate allowances to allow the person to recover from fatigue and, where necessary, an additional allowance to cover contingent elements which may occur but have not been observed. The total observation time should be used to calculate acyclic tasks or task that do not repeat more than one time per shift.

Cycle time is the total time from the beginning to the end of your process, as defined by you and your customer. Cycle time includes process time, during which a unit is acted upon to bring it closer to an output, and delay time, during which a unit of work is spent waiting to take the next action and should be used in cyclic activities.
The total observation time and cycle time could be collected in any unit of measurement; however, they must be converted into seconds to be used in the ergonomics tools.
The next steps are determining the single extortion time of non-neutral postures in seconds and count the number of exertions during the total observation time or the cycle time.
Durations of individual exertions and the total cycle time can be measured manually with a stopwatch of the beginnings and ends of the exertions and job cycle. The duration-of-exertion task variable represents the percent exertion time per job cycle and is calculated by dividing the total exertion time by the cycle time and multiplying by 100. This value appears automatically in the Strain Index worksheet.

Counts of exertions can be made manually, and the efforts-per-minute task variable is calculated by dividing the number of exertions per job cycle by the total cycle time.
The effort per minutes is automatically calculated in the worksheet. Use the dropdown options to select the respective multiplier.



Risk Factor	Rating Criterion	Observation			Multiplier	Left	Right
Duration of Exertion (% of Cycle)	< 10%	Calculated Duration of Exertion (from inputs below)			0,5	1,5	1,5
	10-29%	User Inputs	Left	Right	1,0		
	30-49%	Total observation time (sec.)		5760	1,5		
	50-79%	Single exertion time (sec.)		120	2,0		
	≥ 80%	Number of exertions during observation time		25	3,0		
		Calculated Duration of Exertion (%)		52,1 %			
Efforts Per Minute	< 4	Calculated Efforts Per Minute (from inputs above)			0,5		
	4 - 8		Left	Right	1,0		
	9 - 14			0,26	1,5		
	15 - 19				2,0		
	≥ 20				3,0		

Data on duration of task per day can be measured, but it is usually ascertained by interviewing workers and supervisors. Ratings corresponding to these data are assigned using the ratings table.

The strain index score is the product of the six multipliers. The score appears automatically in the worksheet after completing all multipliers in the blue column. The color of score refers to the respective ergonomics risk.

Results Key	SI ≤ 3	Job is probably safe	3,4	3,4
	3 < SI < 7	Job may place individual at increased risk for distal upper extremity disorders		
	7 ≤ SI	Job is probably hazardous		

Interpretation of the strain index score is the last step.

A job or task with a strain index score less than 3.0 would be considered "safe." A job or task with a strain index score greater than 7.0 would be considered "hazardous." When a hazard is predicted, examination of the multiplier values may reveal intervention strategies that would make the job or task safer.

3. NIOSH Lifting Equation

This section provides the technical information for using the lifting equation to evaluate a variety of two-handed manual lifting tasks. Definitions, restrictions/limitations, and data requirements for the revised lifting equation are also provided.

Definition of Terms

- ***Recommended Weight Limit (RWL)***

The RWL is the principal product of the revised NIOSH lifting equation. The RWL is defined for a specific set of task conditions as the weight of the load that nearly all healthy workers could perform over a substantial period of time (e.g., up to 8 hours) without an increased risk of developing lifting-related LBP. By healthy workers, we mean workers who are free of adverse health conditions that would increase their risk of musculoskeletal injury.
The RWL is defined by the following equation:

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

A detailed description of the individual components of the equation are provided in Section 1.3 on page 12.

- ***Lifting Index (LI)***

The LI is a term that provides a relative estimate of the level of physical stress associated with a particular manual lifting task. The estimate of the level of physical stress is defined by the relationship of the weight of the load lifted and the recommended weight limit. The LI is defined by the following equation:

$$LI = \frac{\text{Load Weight (L)}}{\text{Recommended Weight Limit (RWL)}}$$

Terminology and Data Definitions

The following list of brief definitions is useful in applying the revised NIOSH lifting equation. For detailed descriptions of these terms, refer to the individual sections where each is discussed. Methods for measuring these variables and examples are provided in Sections 1 and 2.

Lifting task	Defined as the act of manually grasping an object of definable size and mass with two hands, and vertically moving the object without mechanical assistance.
Load Weight (L)	Weight of the object to be lifted, in pounds or kilograms, including the container.
Horizontal Location (H)	Distance of the hands away from the mid-point between the ankles, in inches or centimeters (measure at the origin and destination of lift). See Figure 1.
Vertical Location (V)	Distance of the hands above the floor, in inches or centimeters (measure at the origin and destination of lift). See Figure 1.
Vertical Travel Distance (D)	Absolute value of the difference between the vertical heights at the destination and origin of the lift, in inches or centimeters.
Asymmetry Angle (A)	Angular measure of how far the object is displaced from the front (mid-sagittal plane) of the worker's body at the beginning or ending of the lift, in degrees (measure at the origin and destination of lift). See Figure 2. The asymmetry angle is defined by the location of the load relative to the worker's mid-sagittal plane, as defined by the neutral body posture, rather than the position of the feet or the extent of body twist.
Neutral Body Position	Describes the position of the body when the hands are directly in front of the body and there is minimal twisting at the legs, torso, or shoulders.
Lifting Frequency(F)	Average number of lifts per minute over a 15-minute period.
Lifting Duration	Three-tiered classification of lifting duration specified by the distribution of work-time and recovery-time (work pattern). Duration

	is classified as either short (1 hour), moderate (1-2 hours), or long (2-8 hours), depending on the work pattern.
Coupling Classification	Classification of the quality of the hand-to-object coupling (e.g., handle, cut-out, or grip). Coupling quality is classified as good, fair, or poor.
Significant Control	Significant control is defined as a condition requiring precision placement of the load at the destination of the lift. This is usually the case when (1) the worker has to re-grasp the load near the destination of the lift, or (2) the worker has to momentarily hold the object at the destination, or (3) the worker has to carefully position or guide the load at the destination.

Lifting Task Limitations

The lifting equation is a tool for assessing the physical stress of two-handed manual lifting tasks. As with any tool, its application is limited to those conditions for which it was designed. Specifically, the lifting equation was designed to meet specific lifting-related criteria that encompass biomechanical, work physiology, and psychophysical assumptions and data, identified above. To the extent that a given lifting task accurately reflects these underlying conditions and criteria, this lifting equation may be appropriately applied.

In summary, the NIOSH Lifting Equation does not apply if any of the following occur:
- Lifting/lowering with one hand
- Lifting/lowering for over 8 hours
- Lifting/lowering while seated or kneeling
- Lifting/lowering in a restricted work space
- Lifting/lowering unstable objects
- Lifting/lowering while carrying, pushing or pulling
- Lifting/lowering with wheelbarrows or shovels
- Lifting/lowering with high speed motion (faster than about 30 inches/second)
- Lifting/lowering with unreasonable foot/floor coupling (< 0.4 coefficient of friction between the sole and the floor)
- Lifting/lowering in an unfavorable environment (i.e., temperature significantly outside 66-79 degrees F (19-26 degrees C) range; relative humidity outside 35-50% range)

For those lifting tasks in which the application of the revised lifting equation is not appropriate, a more comprehensive ergonomic evaluation may be needed to quantify the extent of other physical stressors, such as prolonged or frequent non-neutral back postures or seated postures, cyclic loading (whole body vibration), or unfavorable environmental factors (e.g., extreme heat, cold, humidity, etc.).

The Equation and Its Function

The revised lifting equation for calculating the Recommended Weight Limit (RWL) is based on a multiplicative model that provides a weighting for each of six task variables. The weightings are expressed as coefficients that serve to decrease the load constant, which represents the maximum recommended load weight to be lifted under ideal conditions. The RWL is defined by the following equation:

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

Where:

Load Constant	LC	23 kg	51 LB.
Horizontal Multiplier	HM	(25/H)	(10/H)
Vertical Multiplier	VM	1-(0,003 [V-75])	1-(.0075 [V-30])
Distance Multiplier	DM	0,82 + (4,5/D)	0,82 + (1,8/D)
Asymmetric Multiplier	AM	1- (0,0032A)	1-(0,0032A)
Frequency Multiplier	FM	From Table 5	From Table 5
Coupling Multiplier	CM	From Table 7	From Table 7

The term task variables refers to the measurable task descriptors (i.e., H, V, D, A, F, and C); whereas, the term multipliers refers to the reduction coefficients in the equation (i.e., HM, VM, DM, AM, FM, and CM).
Each multiplier should be computed from the appropriate formula, but in some cases, it will be necessary to use linear interpolation to determine the value of a multiplier, especially when the value of a variable is not directly available from a table. For example, when the measured frequency is not a whole number, the appropriate multiplier must be interpolated between the frequency values in the table for the two values that are closest to the actual frequency.
A brief discussion of the task variables, the restrictions, and the associated multiplier for each component of the model is presented in the following sections.

Horizontal Component

- Definition and Measurement

Horizontal Location (H) is measured from the mid-point of the line joining the inner ankle bones to a point projected on the floor directly below the mid-point of the hand grasps (i.e., load center), as defined by the large middle knuckle of the hand (Figure 1).

Typically, the worker's feet are not aligned with the mid-sagittal plane, as shown in Figure 1, but may be rotated inward or outward. If this is the case, then the mid-sagittal plane is defined by the worker's neutral body posture as defined above.
If significant control is required at the destination (i.e., precision placement), then H should be measured at both the origin and destination of the lift.
Horizontal Location (H) should be measured. In those situations where the H value cannot be measured, then H may be approximated from the following equations:

- **Horizontal Restrictions**

If the horizontal distance is less than 10 inches (25 cm), then H is set to 10 inches (25 cm). Although objects can be carried or held closer than 10 inches from the ankles, most objects that are closer than this cannot be lifted without encountering interference from the abdomen or hyperextending the shoulders. While 25 inches (63 cm) was chosen as the maximum value for H, it is probably too large for shorter workers, particularly when lifting asymmetrically. Furthermore, objects at a distance of more than 25 inches from the ankles normally cannot be lifted vertically without some loss of balance.

- **Horizontal Multiplier**

The Horizontal Multiplier (HM) is 10/H, for H measured in inches, and HM is 25/H, for H measured in centimeters. If H is less than or equal to 10 inches (25 cm), then the multiplier is 1.0. HM decreases with an increase in H value. The multiplier for H is reduced to 0.4 when H is 25 inches (63 cm). If H is greater than 25 inches, then HM = 0.

Vertical Component

- **Definition and Measurement**

Vertical Location (V) is defined as the vertical height of the hands above the floor. V is measured vertically from the floor to the mid-point between the hand grasps, as defined by the large middle knuckle. The coordinate system is illustrated in Figure 1.

- **Vertical Restrictions**

The vertical location (V) is limited by the floor surface and the upper limit of vertical reach for lifting (i.e., 70 inches or 175 cm). The vertical location should be measured at the origin and the destination of the lift to determine the travel distance (D).

- **Vertical Multiplier**

To determine the Vertical Multiplier (VM), the absolute value or deviation of V from an optimum height of 30 inches (75 cm) is calculated. A height of 30 inches above floor level is considered "knuckle height" for a worker of average height (66 inches or 165 cm). The Vertical Multiplier (VM) is (1-(.0075 [V-30])) for V measured in inches, and VM is (1-(.003 [V-75])), for V measured in centimeters.

When V is at 30 inches (75 cm), the vertical multiplier (VM) is 1.0. The value of VM decreases linearly with an increase or decrease in height from this position. At floor level, VM is 0.78, and at 70 inches (175 cm) height VM is 0.7. If V is greater than 70 inches, then VM = 0.

Distance Component

- **Definition and Measurement**

The Vertical Travel Distance variable (D) is defined as the vertical travel distance of the hands between the origin and destination of the lift (Figure 1). For lifting, D can be computed by subtracting the vertical location (V) at the origin of the lift from the corresponding V at the destination of the lift (i.e., D is equal to V at the destination minus V at the origin). For a lowering task, D is equal to V at the origin minus V at the destination.

- **Distance Restrictions**

The variable (D) is assumed to be at least 10 inches (25 cm), and no greater than 70 inches {175 cm}. If the vertical travel distance is less than 10 inches (25 cm), then D should be set to the minimum distance of 10 inches (25 cm).

- **Distance Multiplier**

The Distance Multiplier (DM) is (.82 + (1.8/D)) for D measured in inches, and DM is (.82 + (4.5/D)) for D measured in centimeters. For D less than 10 inches (25 cm) D is assumed to be 10 inches (25 cm), and DM is 1.0. The Distance Multiplier, therefore, decreases gradually with an increase in travel distance. The DM is 1.0 when D is set at 10 inches, (25 cm); DM is 0.85 when D = 70 inches (175 cm). Thus, DM ranges from 1.0 to 0.85 as the D varies from 0 inches (0 cm) to 70 inches (175 cm). See the illustration in Figure 1.

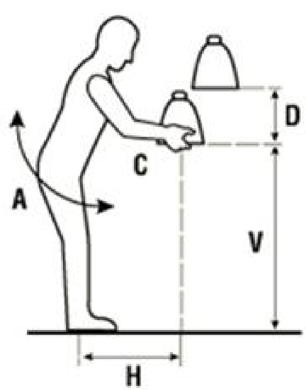


Figure 1

Asymmetry Component

- **Definition and Measurement**

Asymmetry refers to a lift that begins or ends outside the mid-sagittal plane as shown in Figure 2 on page 8. In general, asymmetric lifting should be avoided. If asymmetric lifting cannot be avoided, however, the recommended weight limits are significantly less than those limits used for symmetrical lifting. (5)

An asymmetric lift may be required under the following task or workplace conditions:

1. The origin and destination of the lift are oriented at an angle to each another.
2. The lifting motion is across the body, such as occurs in swinging bags or boxes from one location to another.
3. The lifting is done to maintain body balance in obstructed workplaces, on rough terrain, or on littered floors.
4. Productivity standards require reduced time per lift.

The asymmetric angle (A), which is depicted graphically in Figure 2, is operationally defined as the angle between the asymmetry line and the mid-sagittal line. The asymmetry line is defined as the horizontal line that joins the mid-point between the inner ankle bones and the point projected on the floor directly below the mid-point of the hand grasps, as defined by the large middle knuckle.

The sagittal line is defined as the line passing through the mid-point between the inner ankle bones and lying in the mid-sagittal plane, as defined by the neutral body position (i.e., hands directly in front of the body, with no twisting at the legs, torso, or shoulders). Note: The asymmetry angle is not defined by foot position or the angle of torso twist, but by the location of the load relative to the worker's mid-sagittal plane.

In many cases of asymmetric lifting, the worker will pivot or use a step turn to complete the lift. Since this may vary significantly between workers and between lifts, we have assumed that no pivoting or stepping occurs. Although this assumption may overestimate the reduction in acceptable load weight, it will provide the greatest protection for the worker.

The asymmetry angle (A) must always be measured at the origin of the lift. If significant control is required at the destination, however, then angle A should be measured at both the origin and the destination of the lift.

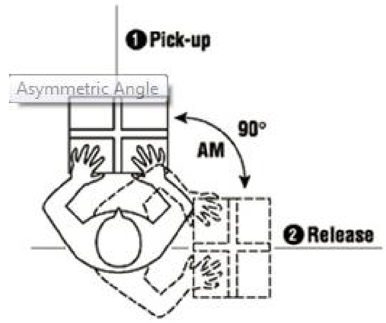


Figure 2

- **Asymmetry Restrictions**

The angle A is limited to the range from 0 degrees to 135 degrees. If A > 135 degrees, then AM is set equal to zero, which results in a RWL of zero, or no load.

- **Asymmetric Multiplier**

The Asymmetric Multiplier (AM) is 1-(.0032A). The AM has a maximum value of 1.0 when the load is lifted directly in front of the body. The AM decreases linearly as the angle of asymmetry (A) increases. The range is from a value of 0.57 at 135 degrees of asymmetry to a value of 1.0 at 0 degrees of asymmetry (i.e., symmetric lift).
If A is greater than 135 degrees, then AM = 0, and the load is zero.

Frequency Component

- **Definition and Measurement**

The frequency multiplier is defined by (a) the number of lifts per minute (frequency), (b) the amount of time engaged in the lifting activity (duration), and (c) the vertical height of the lift from the floor. Lifting frequency (F) refers to the average number of lifts made per minute, as measured over a 15-minute period. Because of the potential variation in work patterns, analysts may have difficulty obtaining an accurate or representative 15-minute work sample for computing the lifting frequency (F). If significant variation exists in the frequency of lifting over the course of the day, analysts should employ standard work sampling techniques to obtain a representative work sample for determining the number of lifts per minute. For those jobs where the frequency varies from session to session, each session should be analyzed separately, but the overall work pattern must still be considered. For more information, most standard industrial engineering or ergonomics texts provide guidance for establishing a representative job sampling strategy (e.g., Eastman Kodak Company, 1986).

- **Lifting Duration**

Lifting duration is classified into three categories -- short-duration, moderate-duration and long-duration. These categories are based on the pattern of continuous work-time and recovery-time (i.e., light work) periods. A continuous work-time period is defined as a period of uninterrupted work. Recovery-time is defined as the duration of light work activity following a period of continuous lifting.

Examples of light work include activities such as sitting at a desk or table, monitoring operations, light assembly work, etc.

1. Short-duration defines lifting tasks that have a work duration of one hour or less, followed by a recovery time equal to 1.2 times the work time.
For example, to be classified as short-duration, a 45-minute lifting job must be followed by at least a 54-minute recovery period prior to initiating a subsequent lifting session. If the required recovery time is not met for a job of one hour or less, and a subsequent lifting session is required, then the total lifting time must be combined to correctly determine the duration category. Moreover, if the recovery period does not meet the time requirement, it is disregarded for purposes of determining the appropriate duration category.

2. Moderate-duration defines lifting tasks that have a duration of more than one hour, but not more than two hours, followed by a recovery period of at least 0.3 times the work time. For example, if a worker continuously lifts for 2 hours, then a recovery period of at least 36 minutes would be required before initiating a subsequent lifting session. If the recovery time requirement is not met, and a subsequent lifting session is required, then the total work time must be added together. If the total work time exceeds 2 hours, then the job must be classified as a long-duration lifting task.

3. Long-duration defines lifting tasks that have a duration of between two and eight hours, with standard industrial rest allowances (e.g., morning, lunch, and afternoon rest breaks).
Note: No weight limits are provided for more than eight hours of work.

- **Frequency Restrictions**

Lifting frequency (F) for repetitive lifting may range from 0.2 lifts/min to a maximum frequency that is dependent on the vertical location of the object (V) and the duration of lifting Table 1. Lifting above the maximum frequency results in a RWL of 0.0. (Except for the special case of discontinuous lifting discussed above, where the maximum frequency is 15 lifts/minute.)

- **Frequency Multiplier**

The FM value depends upon the average number of lifts/min (F), the vertical location (V) of the hands at the origin, and the duration of continuous lifting. For lifting tasks with a frequency less than .2 lifts per minute, set the frequency equal to .2 lifts/minute. For infrequent lifting (i.e., F < .1 lift/minute), however, the recovery period will usually be sufficient to use the 1-hour duration category. The FM value is determined from Table 1

- **Special Frequency Adjustment Procedure**

A special procedure has been developed for determining the appropriate lifting frequency (F) for certain repetitive lifting tasks in which workers do not lift continuously during the 15-minute sampling period. This occurs when the work pattern is such that the worker lifts repetitively for a short time and then performs light work for a short time before starting another cycle. As long as the actual lifting frequency does not exceed 15 lifts per minute, the lifting frequency (F) may be determined for tasks such as this as follows:

1. Compute the total number of lifts performed for the 15-minute period (i.e., lift rate times work time).
2. Divide the total number of lifts by 15.
3. Use the resulting value as the frequency (F) to determine the frequency multiplier (FM) from Table 1.

For example, if the work pattern for a job consists of a series of cyclic sessions requiring 8 minutes of lifting followed by 7 minutes of light work, and the lifting rate during the work sessions is 10 lifts per minute, then the frequency rate (F) that is used to determine the frequency multiplier for this job is equal to (10 x 8)/15 or 5.33 lifts/minute. If the worker lifted continuously for more than 15 minutes, however, then the actual lifting frequency (10 lifts per minute) would be used.

When using this special procedure, the duration category is based on the magnitude of the recovery periods between work sessions, not within work sessions. In other words, if the work pattern is intermittent and the special procedure applies, then the intermittent recovery periods that occur during the 15-minute sampling period are not considered as recovery periods for purposes of determining the duration category.

For example, if the work pattern for a manual lifting job was composed of repetitive cycles consisting of 1 minute of continuous lifting at a rate of 10 lifts/minute, followed by 2 minutes of recovery, the correct procedure would be to adjust the frequency according to the special procedure {i.e., F = (10 lifts/minute x 5 minutes)/15 minutes = 50/15 = 3.4 lifts/minute.}

Table 1: Frequency Multiplier Table

Frequency	<8 Hrs		<2 Hrs		<1 Hrs	
Lifts/min	V<75	V>=75	V<75	V>=75	V<75	V>=75
0,2	0,85	0,85	0,95	0,95	1	1
0,5	0,81	0,81	0,92	0,92	0,97	0,97
1	0,75	0,75	0,88	0,88	0,94	0,94
2	0,65	0,65	0,84	0,84	0,91	0,91
3	0,55	0,55	0,79	0,79	0,88	0,88
4	0,45	0,45	0,72	0,72	0,84	0,84
5	0,35	0,35	0,6	0,6	0,8	0,8
6	0,27	0,27	0,5	0,5	0,75	0,75
7	0,22	0,22	0,42	0,42	0,7	0,7
8	0,18	0,18	0,35	0,35	0,6	0,6
9	0	0,15	0,3	0,3	0,52	0,52
10	0	0,13	0,26	0,26	0,45	0,45
11	0	0	0	0,23	0,41	0,41
12	0	0	0	0,21	0,37	0,37
13	0	0	0	0	0	0,34
14	0	0	0	0	0	0,31
15	0	0	0	0	0	0,28
>15	0	0	0	0	0	0

Coupling Component

- **Definition & Measurement**

The nature of the hand-to-object coupling, or gripping method can affect not only the maximum force a worker can or must exert on the object, but also the vertical location of the hands during the lift. A good coupling will reduce the maximum grasp forces required and increase the acceptable weight for lifting, while a poor coupling will generally require higher maximum grasp forces and decrease the acceptable weight for lifting.

The effectiveness of the coupling is not static but may vary with the distance of the object from the ground, so that a good coupling could become a poor coupling during a single lift. The entire range of the lift should be considered when classifying hand-to-object couplings, with classification based on overall effectiveness. The analyst must classify the coupling as good, fair, or poor. The three categories are defined in Table 2. If there is any doubt about classifying a particular coupling design, the more stressful classification should be selected.

1. An optimal handle design has .75 - 1.5 inches (1.9 to 3.8 cm) diameter, greater than or equal to 4.5 inches (11.5 cm) length, 2 inches (5 cm) clearance, cylindrical shape, and a smooth, non-slip surface.

2. An optimal hand-hold cut-out has the following approximate characteristics: greater than or equal to 1.5-inch (3.8 cm) height, 4.5-inch (11.5 cm) length, semi-oval shape, greater than or equal to 2-inch (5 cm) clearance, smooth non-slip surface, and greater than or equal to 0.25 inches (0.60 cm) container thickness (e.g., double thickness cardboard).

3. An optimal container design has less than or equal to 16 inches (40 cm) frontal length, less than or equal to 12 inches (30 cm) height, and a smooth non-slip surface.

4. A worker should be capable of clamping the fingers at nearly 90 degrees 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 (40 cm), height > 12 inches (30 cm), 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.

Table 2: Hand-to-Container Coupling Classification

GOOD	FAIR	POOR
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.	For containers of optimal design, a "Fair" hand-to- object coupling would be defined as handles or hand- hold cut-outs of less than optimal design.	Containers of less than optimal design or loose parts or irregular objects that are bulky, hard to handle, or have sharp edges.
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.	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.	Lifting non-rigid bags (i.e., bags that sag in the middle).

NOTES:

1. An optimal handle design has 0.75-1.5 inches (1.9 to 3.8cm) diameter, >= 4.5 inches (11.5 cm) length, 2 inches (5 cm) clearance, cylindrical shape, and a smooth, non-slip surface.
2. An optimal hand-hold cut-out has the following approximate characteristics: >= 1.5-inch (3.8 cm) height, 4.5 (11.5 cm) length, semi-oval shape, >= 2 inches (5 cm) clearance, smooth non-slip surface, and >= 0.25 inches (0.60 cm) container thickness (e.g. double thickness cardboard).
3. An optimal container design has <= 16 inches (40 cm) frontal length, <= 12 inches (30 cm) height, and a smooth non-slip surface.
4. A worker should be capable of clamping the fingers nearly 90 degrees 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 (40 cm), height > 12 inches (30 cm), 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.

- **Coupling Multiplier**

Based on the coupling classification and vertical location of the lift, the Coupling Multiplier (CM) is determined from Table 3.
The following decision tree may be helpful in classifying the hand-to-object coupling.

Table 3: Coupling Factor Table

Coupling Type	Couplings	Coupling Multiplier	
		V<30	V>=30
GOOD	1	1	1
FAIR	2	0,95	1
POOR	3	0,9	0,9

The Lifting Index (LI)

As defined earlier, the Lifting Index (LI) provides a relative estimate of the physical stress associated with a manual lifting job.

$$LI = \frac{\text{Load Weight (L)}}{\text{Recommended Weight Limit (RWL)}}$$

Where Load Weight (L) = weight of the object lifted (lbs. or kg).

Using the RWL and LI to Guide Ergonomic Design

The recommended weight limit (RWL) and lifting index (LI) can be used to guide ergonomic design in several ways:

(1) The individual multipliers can be used to identify specific job-related problems. The relative magnitude of each multiplier indicates the relative contribution of each task factor (e.g., horizontal, vertical, frequency, etc.)

(2) The RWL can be used to guide the redesign of existing manual lifting jobs or to design new manual lifting jobs. For example, if the task variables are fixed, then the maximum weight of the load could be selected so as not to exceed the RWL; if the weight is fixed, then the task variables could be optimized so as not to exceed the RWL.

(3) The LI can be used to estimate the relative magnitude of physical stress for a task or job. The greater the LI, the smaller the fraction of workers capable of safely sustaining the level of activity. Thus, two or more job designs could be compared.

(4) The LI can be used to prioritize ergonomic redesign. For example, a series of suspected hazardous jobs could be rank ordered according to the LI and a control strategy could be developed according to the rank ordering (i.e., jobs with lifting indices above 1.0 or higher would benefit the most from redesign).

Lift index interpretation:

- LI < 1: This lift may be acceptable.
- 1 < LI < 3: This lift may increase the risk of low back or lifting injury. Controls should be considered.
- LI > 3: This lift may exceed the capabilities of safely performing the lift for nearly all workers. Redesign of the lifting task is recommended.

Rationale and Limitations for LI

The NIOSH Recommended Weight Limit (RWL) equation and Lifting Index (LI) are based on the concept that the risk of lifting-related low back pain increases as the demands of the lifting task increase. In other words, as the magnitude of the LI increases, (1) the level of the risk for a given worker would be increased, and (2) a greater percentage of the workforce is likely to be at risk for developing lifting-related low back pain. The shape of the risk function, however, is not known. Without additional data showing the relationship between low back pain and the LI, it is impossible to predict the magnitude of the risk for a given

individual or the exact percent of the work population who would be at an elevated risk for low back pain.
To gain a better understanding of the rationale for the development of the RWL and LI, consult the paper entitled Revised NIOSH Equation for the Design and Evaluation of Manual Lifting Tasks by Waters, Putz-Anderson, Garg, and Fine (1993) (Appendix I). This article provides a discussion of the criteria underlying the lifting equation and of the individual multipliers. This article also identifies both the assumptions and uncertainties in the scientific studies that associate manual lifting and low back injuries.

Procedures to use the NIOSH Lifting Equation worksheet

The relevant task variables must be carefully measured and clearly recorded in a concise format. A thorough job analysis is required to identify and catalog each independent lifting task that comprises the worker's complete job. 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. 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).

5. 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 work shift.

6. Coupling type. Classify the hand-to-container coupling based on Table 2.
7. All data above should be imputed in the respective blue cell in the NIOSH Lifting Equation worksheet.

8. The Multipliers, Recommended Weight Limit and Lift Index will be calculated automatically in the work sheet, Figure 3.

Figure 3: NIOSH worksheet

	Data	Restrictions	Multiplier	
Load Weight (L) (kg)				
Load Constant (kg)	23		LC	
Horizontal Location (Ho) (cm)		H>=25 H<63	HM	
Vertical Location (Vo) (cm)		V<175	VM	
Vertical Travel Distance (|Vo - Vd|)		D>=25 D<175	DM	
Asymmetry Angle (A) (degrees)		A<135	AM	
Lifting Duration (hours)				
Lifting Frequency (F) (lifts/minute)			FM	
Coupling (C)			CM	

4. Matrix for exposure time calculation

The Matrix for exposure time calculation (Annex 1) was developed to support and facilitate the using of ergonomics assessment tools and contend 2 main matrices, the Body part exposure time worksheet (Figure 4) and Vertical lifting matrix (Figure 5) to be used to collect the information necessaries for the ergonomics assessment tools.

It is recommended to print this work and fill in the worksheet with the findings related to the workstation and transfer these information to the excel worksheet.

The Body part exposure time worksheet is recommended to use for all workstations. It can use to collect the task information, body part involved during the task and time of the left side and right side. Data of weight and effort should be included too.

Figure 4: The Body part exposure time worksheet

Body part exposure time worksheet

Date: ____________ **Task:** ____________
BU: ____________ **Supervisor:** ____________
Dept: ____________ **Evaluator:** ____________

Total observation time (sec.) ____

Sequence	Taks	Body of part	Left - time (seconds)	Right - time (seconds)	Weight (kg)/ Effort (kgf)	OBS
1						
2						
3						

Neck
Shoulders
Back
Arms/ Elbows
Wrists/ Hands/ Fingers
Legs/ Knees
Ankles/ Feet/ Toes
Neutral position

The Vertical lifting matrix must be used only in the manual lifting operations. It is recommended to print this work and fill in the worksheet with the findings related to the workstation and transfer these information to the excel worksheet.

Figure 5: Vertical lifting matrix

Vertical lifting matrix

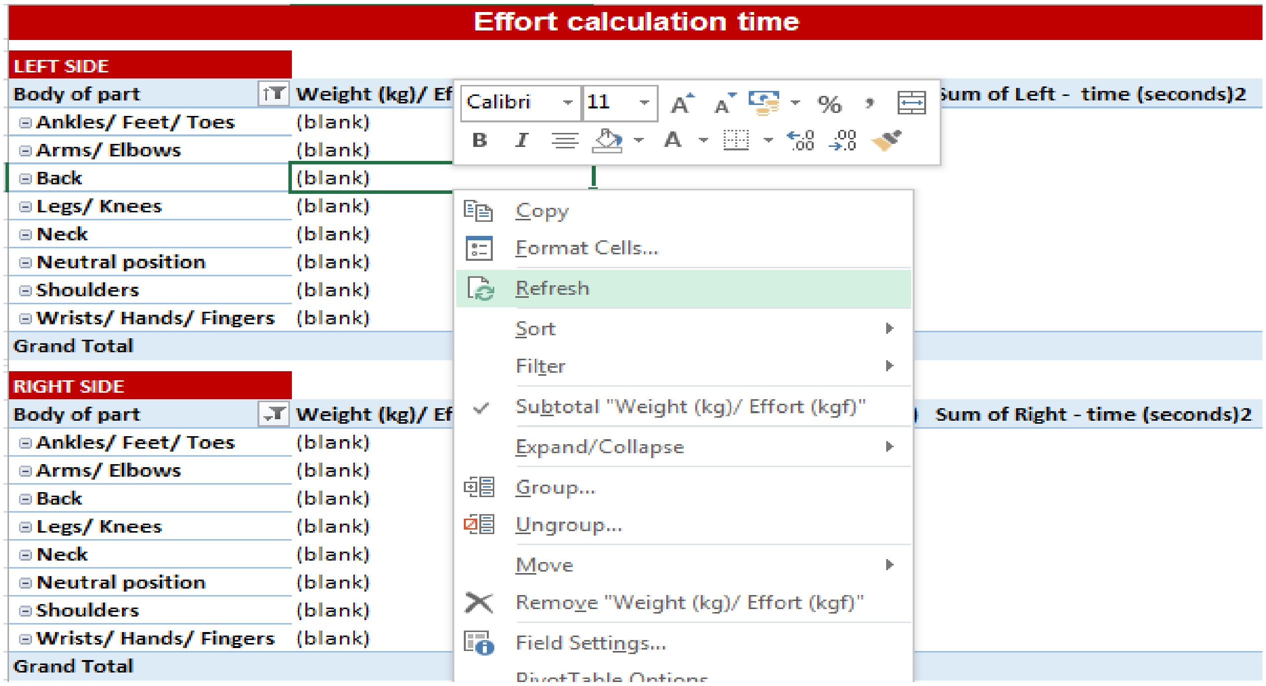
Date: ____________ **Task:** ____________
BU: ____________ **Supervisor:** ____________
Dept: ____________ **Evaluator:** ____________

1) Load weight (kg)	
2) Distance between the ankle bones to the the mid-point of the hand grasps (cm)	
3) Distance vertical height of the hands above the floor of the origin of the lift (cm)	
4) Distance vertical height of the hands above the floor of the destination of the lift (cm)	
5) Body movement angle - torsion (degrees)	
6) Lifting Duration (hours) - Short: < 1 hour / Moderate: > 1 hour but < 2 hours/ Long: > 2 hours but < 8 hours	
7) Number of lifts per minute	
8) Type of couple (good, fair or poor)	

All these data will fill in the NIOSH worksheet and the ergonomics risk will be calculated automatically in the excel sheet.

After entering the Body part exposure time data and Vertical lifting matrix when necessary, go to the Effort calculation time (Figure 6) and, using the left bottom of the mouse and refresh the worksheet.

Figure 6: Effort calculation time



Data from Body part exposure time worksheet will automatically populate the cells related to Duration of Exertion and Efforts per Minute in the Strain Index Worksheet (Figure 7) and Cont. Effort Duration and Effort Frequency in the Rodgers Muscle Fatigue Analysis Worksheet (Figure 8).

Figure 7: Duration of Exertion and Efforts per Minute in the Strain Index Worksheet

Strain Index Worksheet

Date:		Task:	
BU:		Supervisor:	
Dept:		Evaluator:	

Risk Factor	Rating Criterion	Observation			Multiplier	Left	Right
Duration of Exertion (% of Cycle)	< 10%	Calculated Duration of Exertion (from inputs below)			0,5	#DIV/0!	#DIV/0!
	10-29%	User Inputs	Left	Right	1,0		
	30-49%	Total observation time (sec.)	0	0	1,5		
	50-79%	Single exertion time (sec.)	#DIV/0!	#DIV/0!	2,0		
	≥ 80%	Number of exertions during observation time	0	0	3,0		
		Calculated Duration of Exertion (%)	#DIV/0!	#DIV/0!			
Efforts Per Minute	< 4	Calculated Efforts Per Minute (from inputs above)			0,5	#DIV/0!	#DIV/0!
	4 - 8		Left	Right	1,0		
	9 - 14		#DIV/0!	#DIV/0!	1,5		
	15 - 19				2,0		
	≥ 20				3,0		

Figure 8: Cont. Effort Duration and Effort Frequency in the Rodgers Muscle Fatigue Analysis Worksheet

Rodgers Muscle Fatigue Analysis Worksheet

Date:		Task:	
BU:		Supervisor:	
Dept:		Evaluator:	

Table A	Effort Level (If the effort cannot be exerted by most people, enter 4 for Effort)				Scores			Overall Priority
Region	*Light (1)*	*Moderate (2)*	*Heavy (3)*		*Effort Level* (See Table A)	*Cont. Effort Duration* (See Table B)	*Effort Frequency* (See Table B)	
Neck	Neutral neck: head turned partly to side; backor forward slighly; back leaning forward 0-20 degrees	Head turned to side; head fully back; head forward about 20 degrees	Same as moderate but with force or weight; head stretched forward (chin tucked into chest)			#DIV/0!	1	#DIV/0!
Shoulders	Neutral arms; arms slightly away from sides; arms extended with some support	Arms away from body, no support; working overhead or behind	Exerting forces or holding weight with arms away from body or overhead	Right		#DIV/0!	1	#DIV/0!
				Left		#DIV/0!	1	#DIV/0!

5. Annexes

Annex 1 Matrix for exposure time calculation

Annex%201%20Matrix%20for%20exposur