ErgoPlus

NIOSH Lifting Equation

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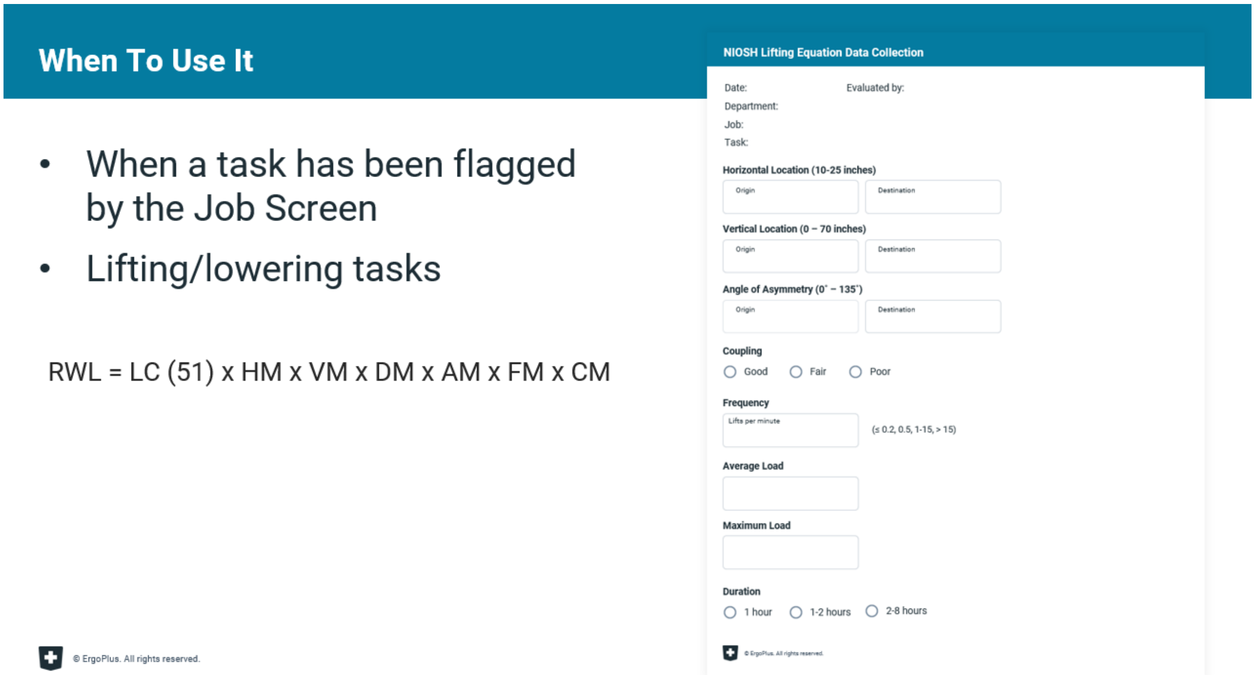
When to Use the NIOSH Lifting Equation

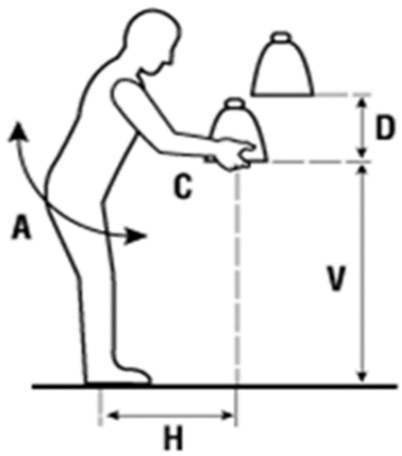


The NIOSH Lifting Equation is a task-level assessment tool used to evaluate lifting and lowering tasks.

Inputs

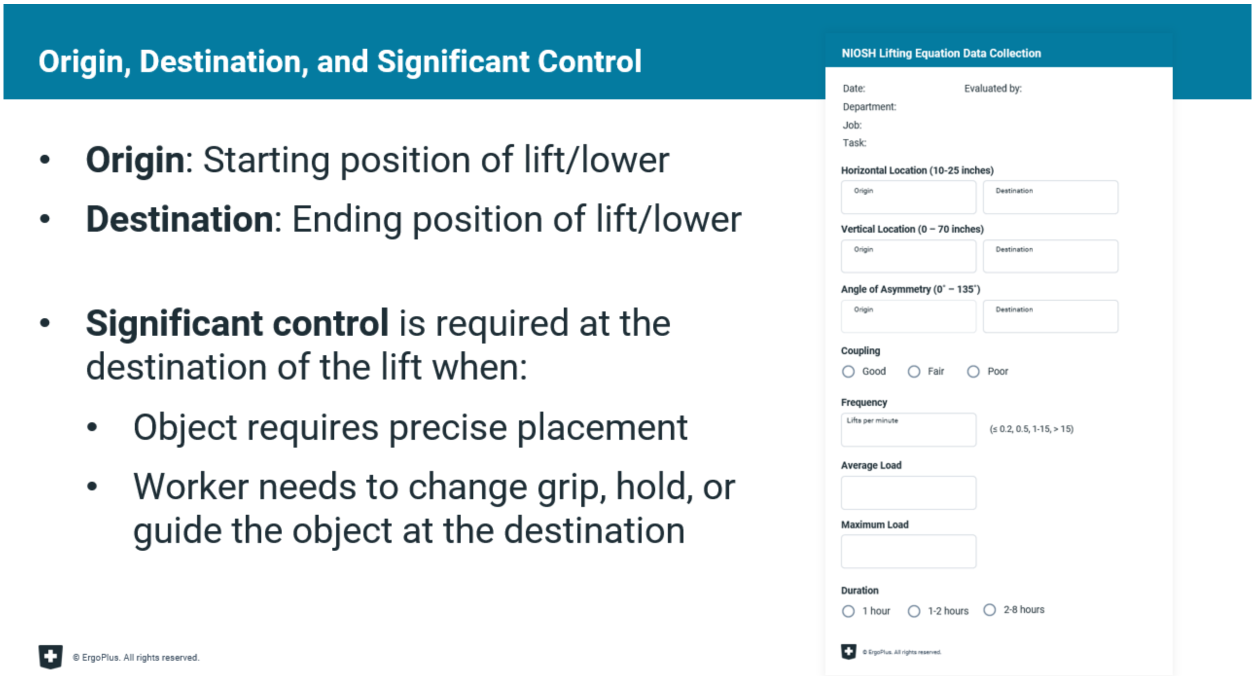
Inputs

- Significant control
- Horizontal Location (origin and destination)
- Vertical Location (origin and destination)
- Angle of Asymmetry (origin and destination)
- Coupling
- Frequency
- Average Load
- Maximum Load
- Duration



There are 9 inputs for NIOSH Lifting Equation assessments. The objective for this lesson is to get you comfortable with each of these task variables. Let’s get started!

Origin, Destination, and Significant Control



The first thing to look for when you're doing this assessment is to find the origin and destination of the lift/lower. The origin is the starting point of the lift/lower, the point at which the weight of the object is loaded onto the hands and moved vertically. The destination is the ending position of the lift/lower, the point at which the weight of the object is unloaded from the hands and stops moving vertically.

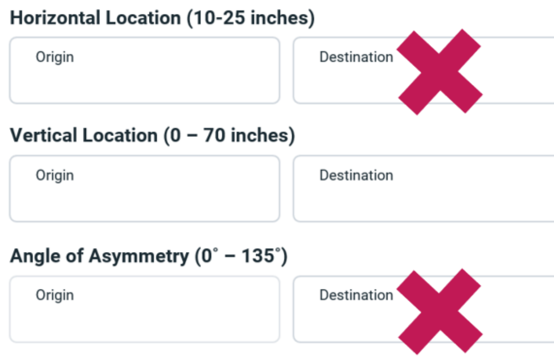
Significant control is a condition of the task that requires precision placement of the load at the destination of the lift. For example, when an object is fragile and careful placement is needed to protect the object from damage. Or, the worker needs to change grip or hold or guide the object at the lifting or lowering destination.

If any of these conditions exist, significant control at the destination is required.

Significant Control

Origin, Destination, and Significant Control

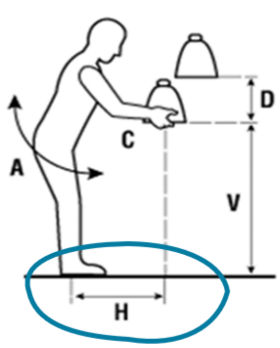
- If significant control is not required at the destination of the lift, you do not need to record the Destination variable for Horizontal Location or Angle of Asymmetry

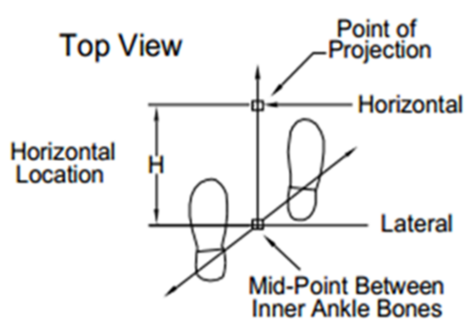


Horizontal Location Overview

Horizontal Location

Horizontal Location of the Object (H) – Measure and record the horizontal location of the hands at the start (origin) of the lifting or lowering task. Measure and record the horizontal location of the hands at the end (destination) of the lifting task only if significant control is required.





Horizontal Location (continued)

Horizontal Location

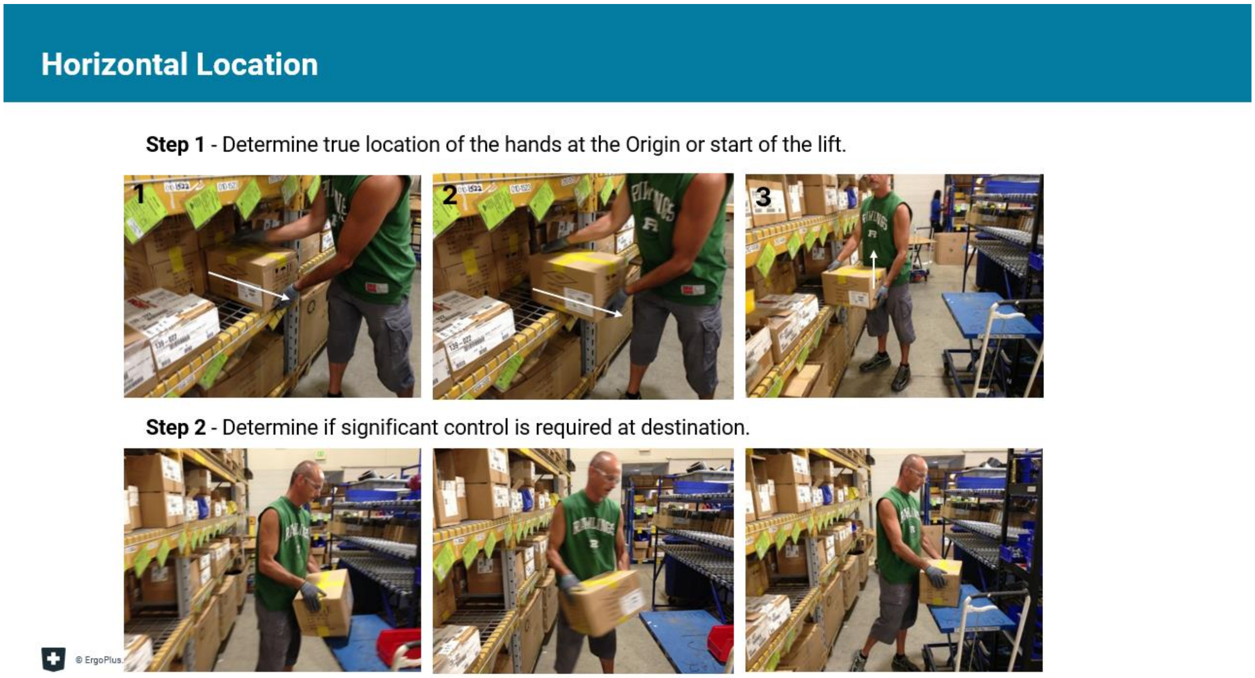
Horizontal Location (H)

- Minimum of 10” (or 25 cm)
- Maximum of 25” (or 63 cm)

The horizontal location is determined by measuring the distance (inches or centimeters) between the point projected on the floor directly below the mid-point of the hands grasping the object (load center), and the mid-point of a line between the inside ankle bones:

The horizontal location distance will be between a minimum of 10” (or 25 cm) and a maximum of 25” (or 63 cm). The H distance could possibly be measured at less than 10”, but even if this is the case you will still use the minimum of 10” (or 25 cm). NIOSH acknowledges (application manual) that it may be possible for some workers to lift and hold an object closer than 10”, but this can’t be accomplished without hyperextension of the shoulders. Additionally, NIOSH determined 25” as the maximum H distance because objects cannot typically be lifted at a greater distance without the worker losing forward balance. If the horizontal location exceeds 25” or 63 cm, the Horizontal Multiplier (HM) is 0 which would indicate a RWL of 0 pounds and an unsafe lifting condition.

Horizontal Location (continued)

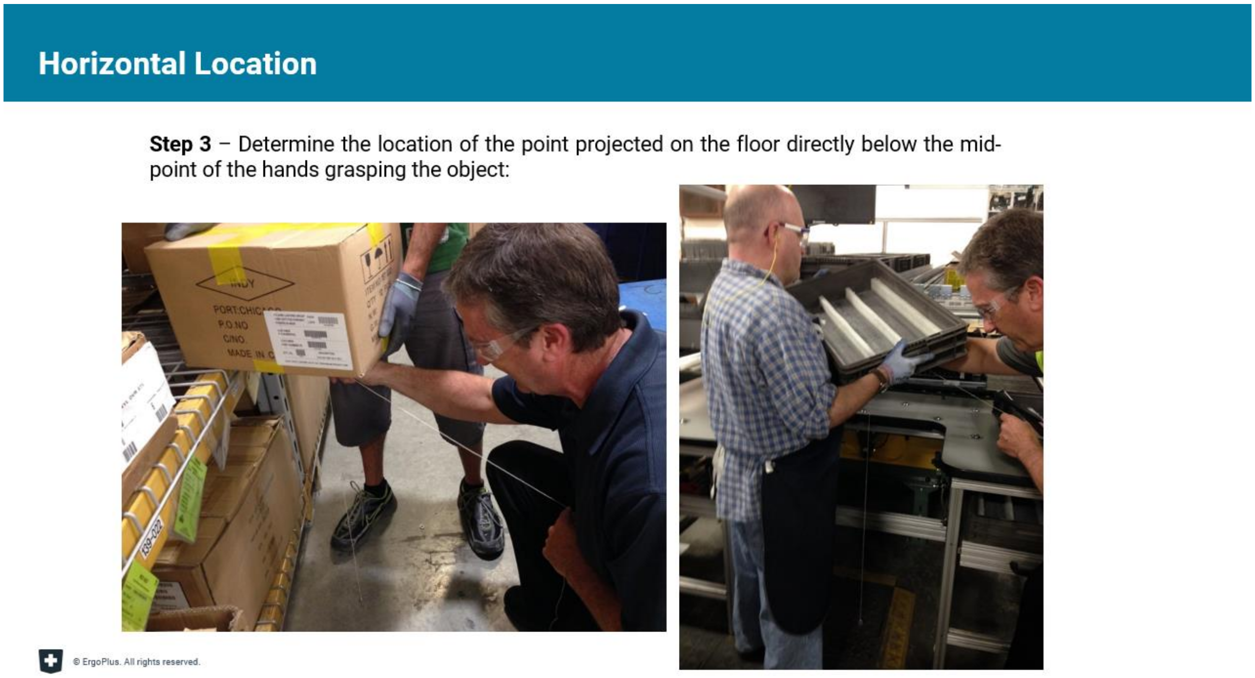


To determine the Horizontal Location (H):

Step 1 - Determine the true origin (start position) of the lifting/lowering task, and the destination (ending position) of the task. Remember that the starting point of sliding the object closer to the body is not the origin or start of the lift. The location of the hands in pictures #1 & #2 is NOT the origin of the lift, because the worker slides the object to the edge of the storage rack. Measurements should be taken at the point where the object is actually picked up or lifted, in this case from edge of the storage rack as shown in picture #3.

Step 2 - We also need to know whether or not significant control of the object being lifted or lowered is required at the destination of the lift. In this case, precision or careful placement of the object is NOT required at the destination. The object is not fragile can be placed on the cart without significant control, caution or precision. Therefore, it’s not necessary to measure the horizontal location of the hands at the destination in this example. If significant control IS required at the destination of the lift, then you will need to measure and record H at the destination as well as the origin.

Horizontal Location (continued)



Step 3 – Determine the location of the point projected on the floor directly below the mid-point of the hands grasping the object.

To accomplish this measurement, I recommend using a string with a small washer tied to one end. The string is placed at the mid-point of the hands as they grasp the object being lifted, or the load center. Allow the washer to fall directly from the load center to the floor, marking the location of the mid-point of the hands as they grasp the object being lifted. You can then drop the string and leave the washer in place.

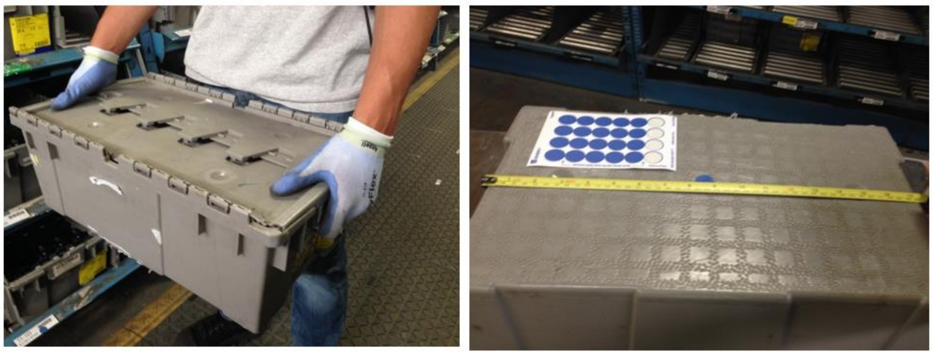
I would also recommend using an empty container whenever asking the worker to help you determine the H location. You don't want to have the worker sustain a heavy lift while you take the time to determine the location on the floor directly below the mid-point of the hands. The last thing that you want to do is place unnecessary fatigue or strain on the worker.

If it's not possible to use an empty container, you can have the worker simulate the lift with approximate positions of the hands without using an object.

Horizontal Location (continued)

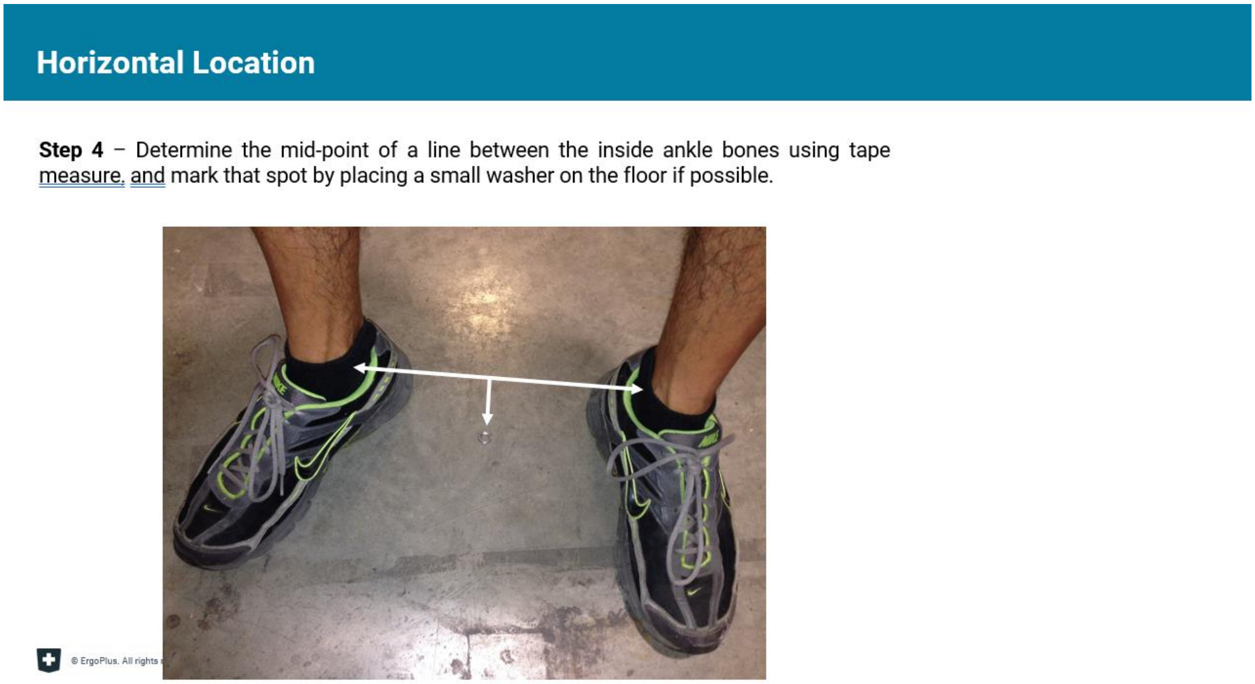
Horizontal Location

Mid-point of hands grasping the object (load center):



To project to a point on the floor directly below the mid-point of the hands, it's helpful to mark the load center location on the bottom of the object. I simply turn the object bottom up, and then measure and mark the load center location with a small sticker. You can then hold the top of the string at this mark and allow the washer to fall to the floor directly below this point, marking the point on the floor directly below the mid-point of the hands.

Horizontal Location (continued)

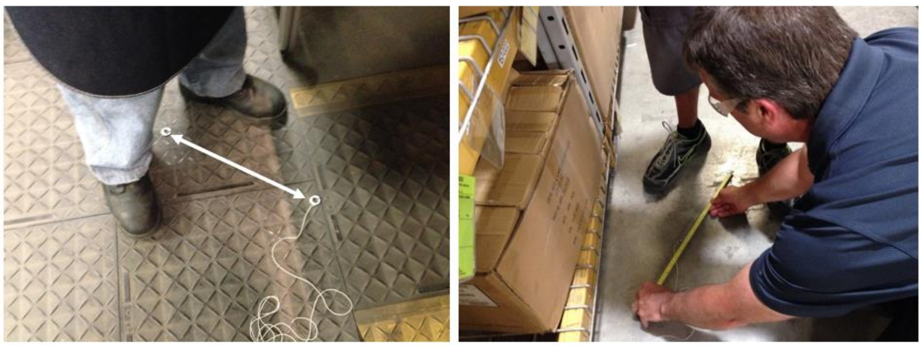


Step 4 – Determine the mid-point of a line between the inside ankle bones using tape measure, and mark that spot by placing a small washer on the floor if possible.

Horizontal Location (continued)

Horizontal Location

Step 5 – Determine the H location by measuring the distance between the two washers, and enter this number on your data collection worksheet under H at the origin of the lift.



You should now have one washer marking the location of the mid-point of the hands grasping the object, and the second washer at the mid-point of a line between the inside ankle bones. Now, all you need to do is measure the distance between these two points to determine the Horizontal Location (H).

Enter this number on your data collection worksheet under H at the origin of the lift.

Horizontal Location (continued)

Horizontal Location

On occasion, you may not be able to project all the way to the floor when obstructed by a horizontal surface. If the body is in a neutral position, where worker's feet, hips, and shoulders are aligned in the mid-line or frontal plane of body and the hands are directly in front of the body, an alternate method can be used to obtain the Horizontal location of the lift. If this is the case, a simple way to determine the H location is to measure from the hand grasp (at the middle knuckle 3rd MCP joint) to the mid-line of the body as pictured.

Remember: This method is NOT to be used:

1) If any asymmetry exists (twisting at the legs, torso, or shoulders)

2) If the feet are in an uneven or offset position outside the midline

3) If the (hands are not directly in front of the body)

4) If the torso is leaning forward

If any of these conditions exist, you should use the string and washer technique described previously.

Horizontal Location (continued)

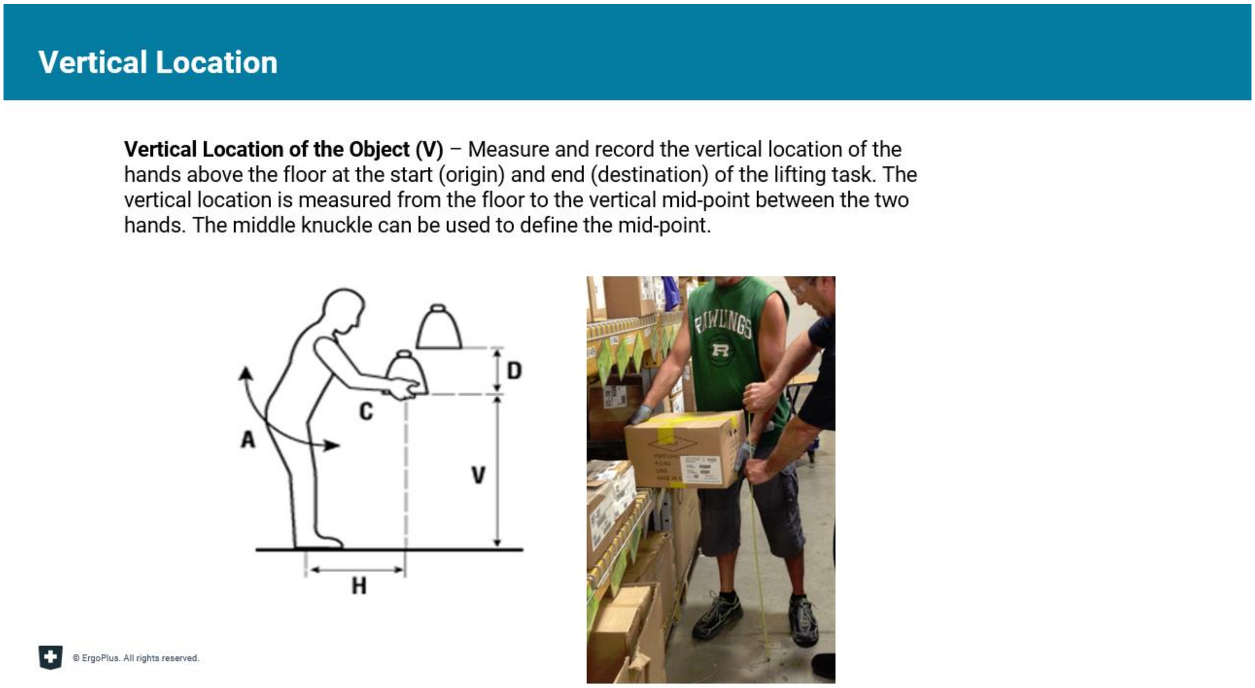
Horizontal Location

If obstructed from projecting to the floor by a horizontal surface, or if the body is NOT in a neutral position, you can use the string and washer technique described previously in two steps to measure the horizontal location of the hands.

In this example, it’s not possible to project from the mid-point of the hands directly to the floor because the horizontal surface (base) of the machine creates an obstruction. So in this case you can use the measuring procedure in two different steps. First, project to a point on the work surface directly below the mid-point of the hands and measure the distance between this point and the machine base edge. Next, project to a point on the floor directly below the edge of the machine base. Finally, measure the distance from this projected point on the floor to the mid-point of a line between the inside ankle bones. If these two measurements are 14” and 5”, the Horizontal Location of the hands would be sum of the two measurements which is 19”.

There may be occasions when you’re unable to slow down or interrupt the production process to obtain exact measurements. If this is the case, you may be forced to best estimates for the horizontal and vertical locations. If best estimates are used, I would recommend being conservative and always disclose and document that locations were estimated as it was not possible to obtain exact measurements.

Vertical Location



Vertical Location of the Object (V) – Measure and record the vertical location of the hands above the floor at the start (origin) and end (destination) of the lifting task. The vertical location is measured from the floor (or standing surface) to the vertical mid-point between the hand grasps as defined by large middle knuckle (3rd MCP joint) of the hand.

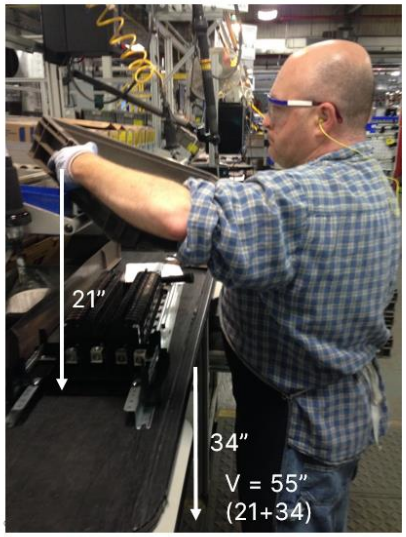
Vertical Location (continued)

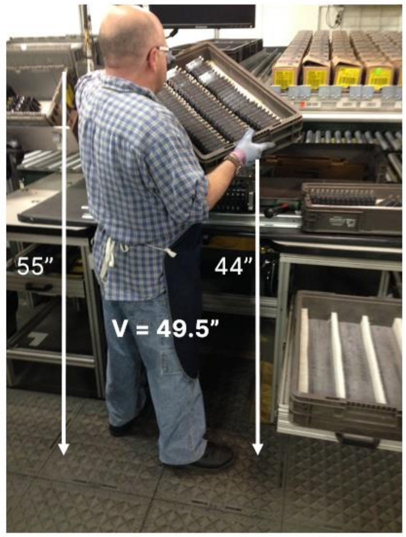
Vertical Location

The vertical location is measured from the floor (or standing surface) to the vertical mid-point between the hands as they grasp the object as defined by large middle knuckle (3rd MCP joint) of the hand. If hand positions are parallel to the floor (left), the measurement can simply be made between one hand grasp to the floor. If the hand positions are offset (one hand higher than the other), you will measure both hand positions and average the two for the correct vertical location of the hands. In the example on the right, the left hand position is 28” and the right hand position is 36”. Therefore, the Vertical Location (V) of the Hands would be 32”.

Vertical Location (continued)

Vertical Location





In this example, it’s not possible to measure from the mid-point of the left hand grasp directly to the floor because the horizontal work surface creates an obstruction. So in this case you’ll need to measure the vertical location of the hands (V) in two different steps. First, measure the distance between the large middle knuckle of the left hand and the horizontal work surface. Next, measure the distance between the horizontal work surface and the floor, and then add these two values together. In this case, the distance between the hand grasp and the work surface is 21” and the distance between the work surface and the floor is 34”.

So the Vertical Location (V) of the left hand grasp is 55” (21+34 = 55”)

In this example the hand positions are again offset (one hand higher than the other), so you will simply average the two positions for the correct vertical location of the hands. The left hand position is 55” and the right hand position is 44”, add these two values and divide by 2. So, the Vertical Location (V) of the Hands in this example is 49.5” (55+44= 99/2 = 49.5).

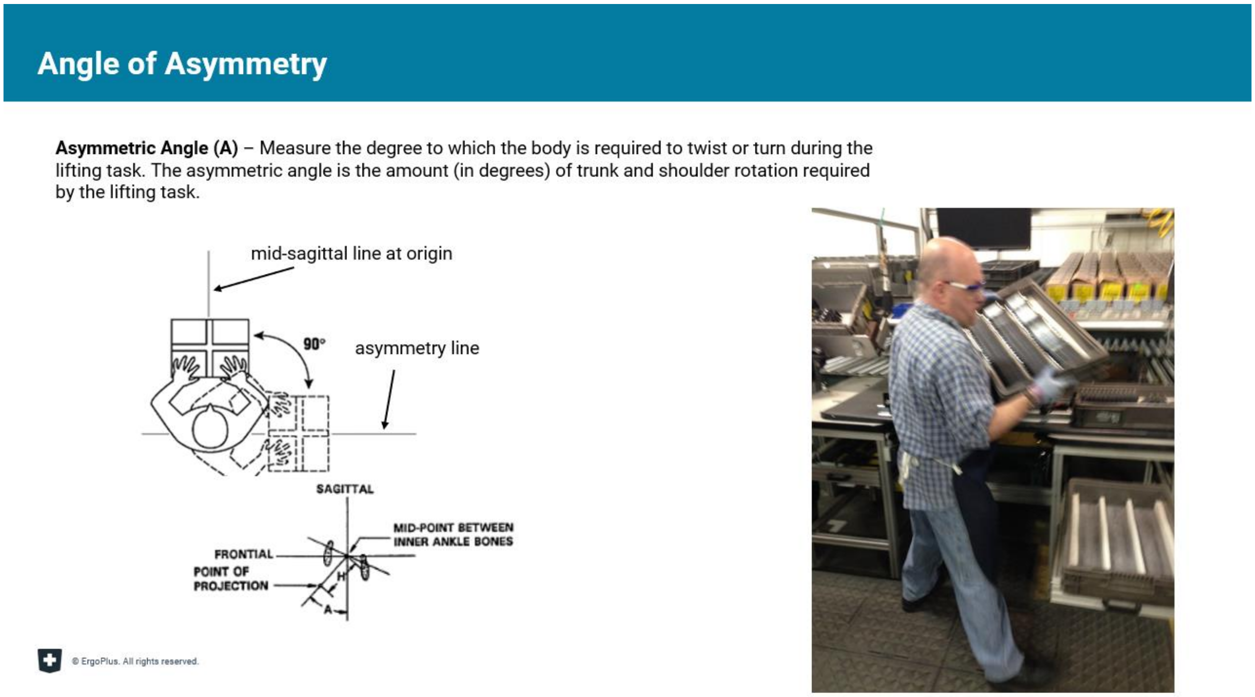
Vertical Location (continued)

Vertical Location

Vertical Location (V) Minimum of 0”, Maximum of 70” (175 cm)

The Vertical Location (V) value will be between 0” or cm (floor level) and the upper limit of reaching of 70” (or 175 cm). So, 0 will be the minimum and 70” (or 175cm) will be the maximum Vertical Location that you will measure and record. If the vertical location exceeds 70” or 175 cm, the Vertical Multiplier is 0 which would indicate an unsafe lifting condition. The (V) location in the picture on the right is 74”, which is above the maximum safe level of 70”. In this case the VM would be 0, indicating an unsafe lifting condition and RWL of 0 lbs.

Angle of Asymmetry



Asymmetric Angle (A) – To determine the asymmetric angle, you will need to measure the degree to which the body is required to twist or turn during the lifting task. The asymmetric angle is the amount (in degrees) of trunk and shoulder rotation required when the lifting task begins (Origin) or ends (Destination) outside the mid-sagittal plane of the body at an outward angle. For example, when the origin and destination of the lift are at an angle to each other and an object is lifted and moved across the body from one side to the other.

When twisting is an intrinsic part of the lifting task required by the physical design, the Asymmetric Angle (A) is always measured at the origin of the lift. The Asymmetric Angle (A) is measured at the destination only if significant control of the object is required.

The Asymmetric Angle (A) value will be between 0 degrees to 135 degrees. If the Asymmetric Angle (A) required by the lifting task is greater than 135 degrees, then the Asymmetric Multiplier (AM) would be 0. This would indicate an unsafe lifting condition and a RWL of 0 for the task.

Angle of Asymmetry (continued)

Angle of Asymmetry

When the lifting task begins or ends outside the mid-sagittal plane of the body at an outward angle (when object is lifted and moved across the body from one side to the other), you will need to measure the Asymmetric Angle (A).

The Asymmetric Angle (A) is the angle between the asymmetry line (origin or destination) 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 on the object (load center), as defined by the location large middle knuckles. The best time to measure for (A) is when you are measuring the Horizontal (H) position of the hands by projecting on the floor directly below the hand grasps. You will use a goniometer to determine the angle between the asymmetric line and the mid-sagittal line, this measurement can easily be done at the floor level.

In most cases, the worker will position in between the origin and destination of the lift, and the total angle of asymmetry is shared equally between the origin and destination. In this event, if the total angle of asymmetry is measured to be 90 degrees, the Asymmetric Angle (A) at both the origin and destination would be 45 degrees. So, essentially the total angle is shared between the start point and the end point of the lift. However, if the worker is required to twist a full 90 degrees from the mid-sagittal plane to pick up the object at the origin, the Asymmetric Angle (A) would be 90 degrees.

NIOSH acknowledges that lifting techniques and body mechanics will vary significantly between workers and between lifts. The lifting equation applications manual recommends that you assume that workers will not pivot (poor lifting mechanics), because it's difficult to monitor and insure that proper techniques are used by all workers. NIOSH acknowledges that this assumption may cause an overestimation of the Asymmetric multiplier's reduction in the RWL, but indicates that this assumption will provide the most conservative evaluation of the RWL.

In many instances, twisting while performing a lifting task is not caused by the physical aspects of the job design, but rather by the employee using improper lifting technique and body mechanics. For example, a worker can choose to use poor body mechanics by twisting the back and torso instead of stepping and pivoting the feet. Poor body mechanics can be employed by the worker even if asymmetry is not an intrinsic element of the lifting task.

So you may want to consider other factors when determining the true Asymmetric Angle (A) of the lift, if you find that the physical design and characteristics of the work task don't require the worker to twist while lifting. For example, if proper lifting and body mechanics training is regularly conducted and monitoring or supervision of lifting mechanics is well established to insure that the best practice technique is being utilized, you may find that it's not necessary to account for a risk factor that does not exist. If on the other hand, upon observing workers performing the lifting tasks you find that asymmetry during the lifting task is consistently present, then you would certainly want to account for that in your assessment.

Coupling

Coupling

Coupling (C) – Determine the classification of the quality of the coupling between the worker's hands and the object as good, fair, or poor (1, 2, or 3). 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.

Coupling (continued)

Coupling

1 = Good - Optimal design containers with handles of optimal design, or irregular objects where the hand can be easily wrapped around the object.

Good Coupling is characterized by: Optimal design containers with handles of optimal design, or irregular objects where the hand can be easily wrapped around the object.

Optimal Container Design

- <= 16 inches (40 cm) frontal length
- <= 12 inches (30 cm) height
- a smooth non-slip surface

Optimal Handle Design

- .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
- smooth, non-slip surface
- hand can be easily wrapped around irregular objects

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. 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.

Coupling (continued)

Coupling

2 = Fair - Optimal design containers with handles of less than optimal design, optimal design containers with no handles or cut-outs, or irregular objects where the hand can be flexed about 90°.

Fair Coupling is characterized by: Optimal design containers with handles of less than optimal design, optimal design containers with no handles or cut-outs, or irregular objects where the hand can be flexed about 90°. A worker should be capable of flexing (clamping) the fingers nearly 90 degrees under the container, such as required when lifting a cardboard box from the floor.

Coupling (continued)

Coupling

Poor Coupling is characterized by: Less than optimal design container with no handles or cut-outs, irregular or bulky objects that are hard to handle (e.g. bags that sag in the middle), or handles with sharp edges.

Coupling (continued)

Coupling

3 = Poor – A good coupling (left) can turn into a poor coupling (right) as a result of the handle style, as well a significant change in the vertical location of the hands.

Note that in any lifting task a good coupling at the origin (left) can turn into a poor coupling at a high vertical location at the destination (right). In this case, the coupling should be rated as poor for the evaluation of this lifting task.

Frequency

Frequency

Frequency (F) - Determine the average number of lifts per minute for the lifting task being evaluated, this is the lifting frequency.

Minimum: 0.2 lifts/minute
Maximum: 15 lifts/minute

The Frequency (F) value will be between 0.2 lifts/minute and 15 lifts/minute. For lifting tasks with a frequency less than .2 lifts per minute (>1 lift every 5 minutes), you will use the minimum frequency of .2 lifts/minute.

The Frequency Multiplier (FM) value depends upon three variables: 1) the average number of lifts/min (F), 2) the vertical location (V) of the hands at the origin, and 3) the duration of continuous lifting.

Lifting above the maximum frequency results in a RWL of 0 and indicates an unsafe lifting condition.

Determine the average number of lifts per minute of the lifting task being evaluated, this is the lifting frequency. This information can often be verified by asking for average production rates from a group leader, supervisor, or production manager. You can also accomplish this by determining the number of lifts per minute during a short sampling period. NIOSH recommends a 15-minute sampling or observation period.

The Frequency (F) value will be between 0.2 lifts/minute and 15 lifts/minute. For lifting tasks with a frequency less than .2 lifts per minute (>1 lift every 5 minutes), you will use the minimum frequency of .2 lifts/minute.

The Frequency Multiplier (FM) value depends upon three variables: 1) the average number of lifts/min (F), 2) the vertical location (V) of the hands at the origin, and 3) the duration of continuous lifting.

Lifting above the maximum frequency results in a RWL of 0 and indicates an unsafe lifting condition.

Keep in mind that there is potential for a wide variation in the work process throughout a work shift, so you need to verify that the 15-minute sample period is representative of a typical work day. And again, it's important to verify the data that you have collected by comparing to average production rates with the department supervisor or production manager.

Frequency (continued)

Frequency

Special Procedure for Work Pattern Variation:
Frequently, the worker will not lift continuously for 15 minutes. For example, a worker might perform a lifting task at a rate of 7 lifts/minute for 10 minutes, and then perform light non-material handling work (such as paperwork) for 5 minutes to complete the 15-minute work cycle.

In this case you would calculate the total number of lifts in the entire 15-minute cycle (7 lifts/minute x 10 minutes = 70 lifts), and then divide this number by 15. So, the resulting calculation would be 7x10 = 70/15 or 4.66 lifts/minute.

So, to determine simply obtain or count the total number of lifts performed in a typical 15-minute period of time and divide that total number by 15 (if using a 15-minute sampling period).

Note: If the worker had lifted continuously for the entire 15 minutes at a rate of 7 lifts/minute, then the actual lifting frequency (7 lifts per minute) would be used.

Average and Maximum Load

Average and Maximum Load

Load (L) – Determine the weight of the object lifted. If necessary, use a scale to determine the exact weight. If the weight of the load varies from lift to lift, you should record the average and maximum weights lifted.

Determine the weight of the object lifted. Often, you can obtain the weight of the object from company production or shipping records. If necessary, use the nearest scale in the facility to determine the exact weight. (You will frequently be able to find a scale in shipping and receiving departments.)

If the weight of the load varies from lift to lift, you should record the average and maximum weights lifted.

Duration

Duration

Duration (Dur) – Determine the lifting duration as classified into one of three categories: Enter 1 for short-duration, 2 for moderate-duration and 8 for long-duration as follows:

1 = Short - lifting ≤ 1 hour with recovery time ≥ 1.2 X work time

2 = Moderate - lifting between 1 and 2 hours with recovery time ≥ 0.3 X lifting time

8 = Long - lifting between 2 and 8 hours with standard industrial rest allowances

These categories are based on the pattern of continuous work-time and recovery-time.

A continuous work-time 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 administrative work, monitoring operations, light assembly work, etc.

Duration (continued)

Duration

1 = Short - lifting ≤ 1 hour with recovery time ≥ 1.2 X work time

Short duration includes lifting tasks that have a work cycle duration of 1 hour or less, followed by a recovery time of at least 1.2 times the work time. If the recovery time requirement is not met, and another lifting session is immediately required, then the total work time must be added together. If the total work time exceeds 1 hour, then the job must be classified as a moderate-duration lifting task.

Example: A worker performs lifting task continuously for 25 minutes, then performs light work tasks for 15 minutes, and then lifts for an additional 45-minute period. In this case, the recovery time between lifting sessions (15 minutes) is less than 1.2 times the initial 25-minute work time (25 min x 1.2 = 30 min). Therefore, the two work times (25 minutes and 45 minutes) must be added together to determine the duration. Since the total work time (70 minutes) exceeds 1 hour, the job is classified as moderate-duration.

Duration (continued)

Duration

2 = Moderate - lifting between 1 and 2 hours with recovery time ≥ 0.3 X lifting time

Moderate duration includes 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. So If a worker continuously lifts for 2 hours, then a recovery period of at least 36 minutes (120 min x .3 = 36 min) would be required before initiating a subsequent lifting session. If the recovery time requirement is not met, and another lifting session is subsequently 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.

Example: A worker performs a lifting task continuously 90 minutes, then performs light work for 15 minutes, and then subsequently performs the lifting tasks for an another 90 minutes. In this case, the recovery time between lifting sessions (15 minutes) is less than .3 times the initial 90-minute work time (90 min x .3 = 27 min). Because the recovery time requirement is not met in this case, the two work times (90 minutes and 90 minutes) must be added together to determine the duration. Since the total work time (180 minutes) exceeds 2 hours, the job is classified as long-duration.

Duration (continued)

Duration

3 = Long - lifting between 2 and 8 hours with standard industrial rest allowances for lunch and rest breaks.

Note: No weight limits are provided for more than eight hours of work.

NIOSH Lifting Equation Outputs

Outputs

RESULTS

Risk

Risk Index	2.36	3.64

	Origin	Destination
Recommended Weight Limit(RWL)	16.91	10.98
Frequency Independant RWL (FIRWL)	28.19	18.31
Lifting Index (LI)	2.36	3.64
Frequency Independent LI (FILI)	1.60	2.46

Multipliers

HM	1.00	0.50
VM	0.78	0.96
DM	0.87	0.87
AM	0.86	0.86
CM	0.95	1.00
FM	0.60	0.60

SAVE CANCEL

The outputs of the NIOSH Lifting Equation can be used to guide or engineer lifting task design in the following ways:

1) The individual multipliers that determine the RWL can be used to identify specific weaknesses in the design.
2) The LI can be used to estimate the relative physical stress and injury risk for a task or job. The higher the LI value, the smaller the percentage of workers capable of safely performing these job demands. Thus, injury risk of two or more job designs could be compared.
3) The LI can also be used to prioritize ergonomic redesign efforts. Jobs can be ranked by LI and a control strategy can be implemented based on a priority order of the jobs or individual lifting tasks.

NIOSH Lifting Equation Outputs (continued)

Outputs

RWL = LC (51) x HM x VM x DM x AM x FM x CM

Recommended Weight Limit (RWL)
Answers, "Is this weight too heavy for the task?"

Lifting Index (LI)
Answers, "How significant is the risk?"

> 1.0 High Risk
< 1.0 Nominal Risk

The goal is to design a job / task to be < 1.0!

The primary product or output of the NIOSH lifting equation is the **Recommended Weight Limit (RWL)**, which defines the maximum acceptable weight (load) that nearly all healthy employees could lift or lower for a substantial period of time (up to 8 hours) without increasing the risk of lifting related musculoskeletal disorders (MSD). The RWL answers the question… "Is this weight too heavy for the task?"

In addition, a **Lifting Index (LI)** is calculated to provide a relative estimate of the level of physical stress and MSD risk associated with the manual lifting and lowering tasks evaluated. Lifting Index (LI) Answers the question… "How significant is the risk?"

A Lifting Index value of less than 1.0 indicates a nominal risk to healthy employees. A Lifting Index of 1.0 or more denotes that the task is high risk for some fraction of the population. As the LI increases, the level of low back injury risk increases correspondingly. Therefore, the goal is to design all lifting jobs to accomplish an LI of less than 1.0.

NIOSH Lifting Equation Outputs (continued)

Outputs

Frequency Independent Recommended Weight Limit (FIRWL)
Uses a Frequency Multiplier (FM) of 1.

Frequency Independent Lifting Index (FILI)
= Weight ÷ FIRWL

There are two additional outputs or products of the revised NIOSH Lifting Equation and our NIOSH calculator that you should understand - The Frequency-Independent Recommended Weight Limit (FIRWL) and the Frequency-Independent Lifting Index (FILI). The FIRWL is calculated by using a frequency multiplier (FM) of 1.0 regardless of the task frequency. This effectively removes frequency as a variable, reflecting a weight limit for a single repetition of that task (which allows objective and equal comparison to other single repetition tasks).

The Frequency-Independent Lifting Index (FILI) is calculated by dividing the weight lifted by the FIRWL. The FILI can help identify problems with infrequent lifting tasks if the FILI exceeds the value of 1.0.