

1991 Revised NIOSH Lifting Equation



The 1991 National Institute for Occupational Safety and Health (NIOSH) Lifting Equation (Waters et al., 1993) is a tool for assessing the stresses associated with two-handed lifting and lowering tasks. The NIOSH equation provides the Recommended Weight Limit (RWL). The equation has a multiplicative form with a Load Constant (LC) of 51 lb. multiplied by each of the following multipliers: Asymmetry Multiplier (AM), Coupling Multiplier (CM), Distance Multiplier (DM), Frequency Multiplier (FM), Horizontal location Multiplier (HM), and the Vertical location Multiplier (VM). The multipliers can take values between 0 and 1.0. Dividing the weight of the actual load lifted or lowered (L) by the RWL yields the Lifting Index (LI)

$$\text{RWL} = \text{LC} \times \text{HM} \times \text{VM} \times \text{DM} \times \text{AM} \times \text{FM} \times \text{CM}.$$

where:

H = Horizontal location in inches

V = Vertical location in inches

D = Travel distance in inches

A = Angle of asymmetry in degrees

The 1991 NIOSH equation is applicable for assessment of two-handed lifting and lowering tasks. The equation assumes that other manual materials handling tasks such as pushing, pulling, or carrying are minimal; however, this assumption is unrealistic in many work settings. When these other tasks are performed, it may be necessary to perform a physiological analysis of the job. Additionally, the equation is intended for favorable ambient conditions, and tasks performed in hot (greater than 79°F) and humid

conditions should not be analyzed with the NIOSH equation. The equation is intended for lifting and lowering stable loads while standing with sufficient room. In summary, the NIOSH equation is designed to assess lifting tasks under relatively ideal conditions.

The 1991 NIOSH equation should not be applied if any of the following occur (Waters et al., 1994):

- Lifting/lowering with one hand, 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 (greater than 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 higher or lower than 66 - 79° F, or relative humidity significantly greater or lower than 35 - 50%
- Lifting and carrying farther than two steps

The calculated RWL is compared to the actual load weight to determine if task redesign is needed. If the actual weight exceeds the calculated RWL, task redesign is needed to reduce the risk of lifting-related low back pain. In addition, individual multipliers can identify task factors

that influence the RWL the most. The magnitude of the multiplier indicates its contribution to the RWL. The lower the multiplier, the greater the influence, and the lower the RWL.

Horizontal Location (H) is measured from the midpoint of a line joining the ankles to a point projected on the floor directly below the midpoint of the center of the load, see Figure 1. Although this component should be measured, it can be calculated by $H = 10'' + W/2$ ($H = 25\text{ cm} + W/2$) when vertical location of the hands from the floor is less than 10'' (25cm), where W is the width of the container. If horizontal distance is less than 10'' (25cm), use 10'' (25cm). The horizontal multiplier is calculated by $10''/H$ (25cm/H) or determined from Table 1.

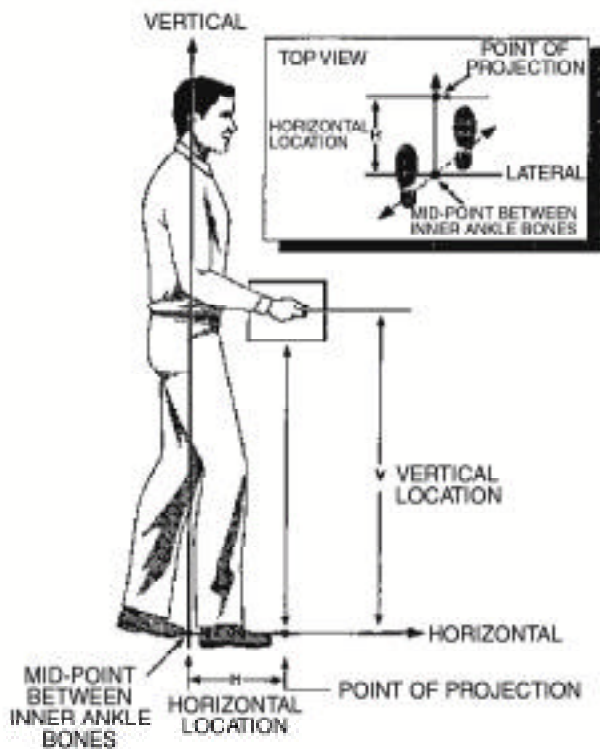


Figure 1. Hand location measurements.

Table 1. Horizontal Multipliers

H (Inches)	HM	H (Centimeters)	HM
10	1.00	25	1.00
11	.91	28	.89
12	.83	30	.83
13	.77	32	.78
14	.71	34	.74
15	.67	36	.69
16	.63	38	.66
17	.59	40	.63
18	.56	42	.60
19	.53	44	.57
20	.50	46	.54
21	.48	48	.52
22	.46	50	.50
23	.44	52	.48
24	.42	54	.46
25	.40	56	.45
> 25	.00	58	.43
		60	.42
		63	.40
		> 63	.00

Vertical Location (V) is the vertical height of the hands above the floor. It is measured from the floor to the height of the middle knuckle, see Figure 1. The maximum measurement is 70'' (175cm). The vertical multiplier is calculated by $(1 - (.0075 \times V - 30))$ for V measured in inches and $(1 - (.003 \times V - 75))$ for V measured in centimeters or determined from Table 2.

Table 2. Vertical Multipliers

V (Inches)	VM	V (Centimeters)	VM
0	.78	0	.78
5	.81	10	.81
10	.85	20	.84
15	.89	30	.87
20	.93	40	.90
25	.96	50	.93
30	1.00	60	.96
35	.96	70	.99
40	.93	80	.99
45	.89	90	.96
50	.85	100	.93
55	.81	110	.90
60	.78	120	.87
65	.74	130	.84
70	.70	140	.81
> 70	.00	150	.78
		160	.75
		170	.72
		175	.70
		> 175	.00

Vertical Travel Distance (D) is the distance of the hands between the origin and destination of the lift. It is calculated by subtracting the vertical location (V) of the origin of the lift from the destination of the lift. Minimum value is 10" (25cm) and maximum value is 70" (175cm). The distance multiplier is calculated by $(.82 + (1.8/D))$ for D measured in inches and $(.82 + (4.5/D))$ for D measured in centimeters or determined from Table 3.

Table 3. Distance Multipliers

D (Inches)	DM	D (Centimeters)	DM
10	1.00	25	1.00
15	.94	40	.93
20	.91	55	.90
25	.89	70	.88
30	.88	85	.87
35	.87	100	.87
40	.87	115	.86
45	.86	130	.86
50	.86	145	.85
55	.85	160	.85
60	.85	175	.85
70	.85	> 175	.00
> 70	.00		

Asymmetry Angle (A) is the angle between the asymmetry line and the mid-sagittal line, shown in Figure 2. The asymmetry line is the horizontal line that joins the midpoint between the inner anklebones and the point projected on the floor directly below the middle knuckle. The sagittal line is the vertical projection of the sagittal plane, which cuts the body into the right and left sides. The asymmetry angle is measured at the origin of the lift and is in the range of 0° to 135°. The asymmetry angle is calculated by 1-.0032A or determined from Table 4.

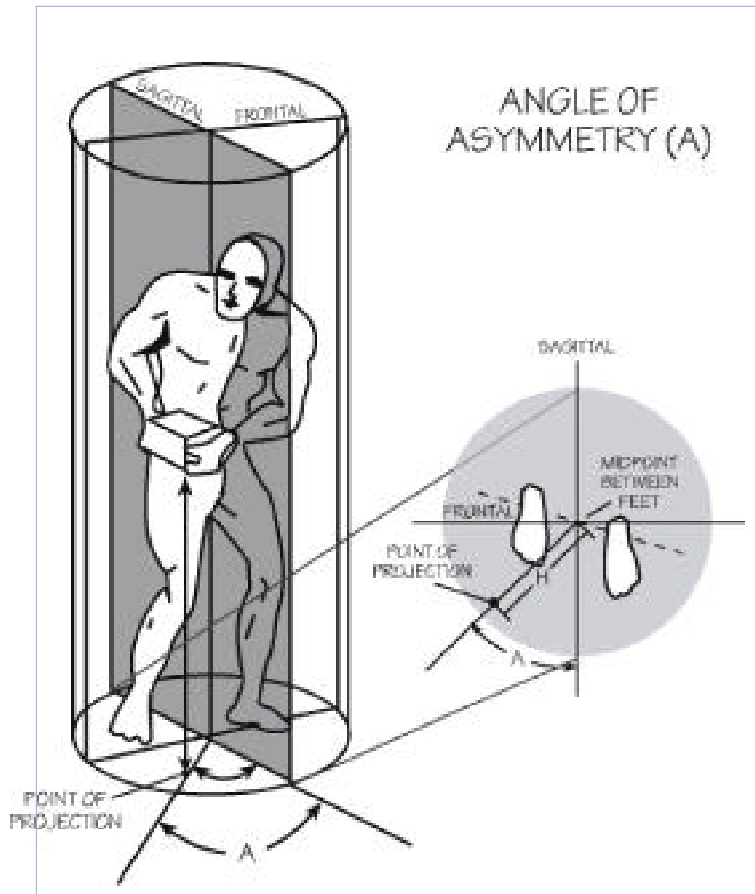


Figure 2. Angle of Asymmetry.

Table 4. Asymmetry Multipliers

A (degrees)	AM
0	1.00
15	.95
30	.90
45	.86
60	.81
75	.76
90	.71
105	.66
120	.62
135	.57
>135	.00

Lifting Frequency (F) is the average number of lifts per minute measured over a 15-minute period. For tasks in which lifting does not occur continuously during the 15 minute period, lifting frequency is determined by dividing the total number of lifts performed for the 15 minute period by 15. For example, if a work cycle consists of 8 minutes of lifting followed by 7 minutes of light activity, and the lifting rate is 10 lifts per minute, then lifting frequency is $(10 \text{ lifts/minutes} \times 8 \text{ minutes of lifting}) / 15 \text{ minutes} = 5.33 \text{ lifts/minute}$. If the worker had lifted at 10 lifts/minute for more than 15 minutes continuously the lifting frequency would be 10 lifts/minute.

The frequency multiplier is determined from Table 5 and is influenced by the lifting frequency, duration, and vertical height of the lift. Lifting duration is short, moderate, or long based on continuous work and recovery time. Continuous work is the period of uninterrupted

work. Recovery time is the period of light work activity after a continuous work period.

Light work activities include sitting at a desk, monitoring equipment, light assembly work, etc. Short duration is a lifting task with a work duration of one hour or less followed by a recovery time of at least 1.2. That means the recovery time is 1.2 times the work time.

Moderate duration is a lifting task with a work duration of more than 1 hour, but less than 2 hours, followed by a recovery time of at least 0.3 times the work time. That means the recovery time is 0.3 times the work time.

Long duration is a lifting duration of 2 to 8 hours, with standard breaks in the morning, for lunch, and in the afternoon. If the required recovery period is not met prior to the next lifting session, the total lifting time is combined to determine the duration category.

Examples of calculating duration:

- 45 minute lifting followed by at least 54 minutes of recovery prior to another lifting session is short duration.
- 30 minutes of continuous lifting, 10 minutes of light activity, 45 minutes of lifting. Since

the 10 minute recovery time does not meet the short duration requirements, the 2 lifting times (30 and 45) are added. Since this exceeds the 1 hour work period for the short duration category, this task is classified as moderate.

Table 5. Frequency Multipliers

Work Duration						
Lifts/Minute	<1 hour		>1 hour, <2 hours		> 2hours, < 8 hours	
	V<30"	V≥30"	V<30"	V≥30"	V<30"	V≥30"
≤ 0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

Coupling Classification (C) is the ability and ease of the worker to grip the object. The entire range of the lift is considered when using Table 6 to classify the coupling.

Table 6. Hand-to-Container Coupling Classifications

Good	Fair	Poor
<ul style="list-style-type: none"> ■ Container of optimal design with handles or handhold cutouts of optimal design (see Notes 1 – 3). ■ Loose parts or irregular objects not normally containerized when the worker can comfortably wrap the hand around the wrist without excessive wrist deviations, awkward postures, or excessive force. 	<ul style="list-style-type: none"> ■ Container of optimal design with handle or handhold cutouts of less than optimal design (see Notes 1 – 3). ■ Container of optimal design without handholds or cutouts that allows the worker to clamp the fingers at nearly 90° under the container. 	<ul style="list-style-type: none"> ■ Containers with frontal length >16" (40cm), height >12" (30cm), rough or slippery surfaces, sharp edges, asymmetric center of mass, unstable contents, or requires the use of gloves. Loose parts, irregular objects that are bulky, hard to handle, or have sharp edges. ■ Lifting non-rigid bags, bags that sag in the middle.

Note:

1. Optimal container design has ≤16" (40cm) frontal length, ≤12" (30cm) height, and smooth non-slip surface.
2. An optimal design handle has 0.75 – 1.5" (1.9 – 3.8cm) diameter, ≥4.5" (11.5cm) length, 2" (5cm) clearance, cylindrical shape, and a smooth, non-slip surface.
3. An optimal handhold cutout has ≥1.5" (3.8cm) height, 4.5" (11.5cm) length, semi-oval shape, ≥2" (5cm) clearance, smooth non-slip surface, and >0.25" (0.60cm) container thickness.

The coupling classification is determined using Table 7.

Table 7. Coupling Multiplier

Coupling Type	V<30" (75cm)	V≥30" (75cm)
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

Detailed below are general design/redesign guidelines for each task factor.

- HM < 1.0: Move load closer to worker by reducing the size of the object or removing horizontal barriers. Avoid lifting at floor level. If a floor level lift is necessary, the object should fit easily between the legs.
- VM < 1.0: Raise or lower either the origin or destination of the lift. Avoid lifting at floor or shoulder level.
- DM < 1.0: Reduce the vertical distance between the origin and destination of the lift.
- AM < 1.0: Move the origin and destination of the lift closer together to reduce the angle of twist OR move the origin and destination of the lift far enough apart to make the worker turn his/her feet and step instead of twisting.
- FM < 1.0: Reduce lifting frequency rate or lifting duration, or provide longer recovery periods.
- CM < 1.0: Improve hand-to-object coupling by providing optimal containers, redesigning the job, or modifying the container.

References

- Waters, Thomas R., V. P. Anderson, A. Garg. *Applications Manual for the Revised NIOSH Lifting Equation*. US Department of Health and Human Services, January 1994.
- Dempsey, P.G. "A Critical Review of Biomechanical, Epidemiological, Physiological and Psychophysical Criteria for Designing Manual Materials Handling Tasks." *Ergonomics*, 1998, 41:1, 73-88.
- Dempsey, P.G., Ayoub, M.M. and Westfall, P.H. (1995). *The NIOSH Lifting Equations: A Closer Look*. In A.C. Bittner and Paul C. Champney (eds.) *Advances in Industrial Ergonomics and Safety VII* (pp. 705-712). London: Taylor and Francis.
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Notes

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