Jiangsu AUREK Intelligent Technology Co., Ltd. · Engineering Research

Occupational Health Risks of Manual Heavy-Load Handling and Engineering Research on Workplace-Injury Prevention

—A Practical Reference for On-Site Risk Identification, Assessment, and Engineering Improvement Based on Ergonomics and the Revised NIOSH Lifting Equation

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Applicable Uses: Preliminary Risk Screening at Manufacturing Sites · Workstation Engineering Improvements · Customer Technical Communication · Internal Training

Nature and Limitations of This Document

This corporate engineering research document provides a reference for identifying risks in the manual handling of heavy loads, conducting ergonomic assessments, and developing engineering improvements at manufacturing sites. Its formulas, worked examples, scores, and tables support engineering risk screening, comparison, and improvement decisions; they do not constitute a medical diagnosis, occupational-disease determination, workplace-injury determination, legal opinion, or interpretation of a mandatory standard. For standard clauses, scopes, current status, and limits, the official standard text, measured site data, and opinions of qualified professional bodies take precedence. This document draws on engineering-improvement practices for industrial material-handling workstations.

Contents

Abstract

Manual handling of heavy loads remains widespread in manufacturing operations, including machine loading/unloading, assembly, packaging and palletizing, warehousing and logistics, and short-distance transfers between processes. Even where forklifts, overhead cranes, conveyors, or automated equipment are available, manual handling remains difficult to eliminate from short-distance, temporary, non-standard-part, and high-frequency small-batch tasks. Traditional management often relies primarily on whether the weight of a single item exceeds a threshold. On-site engineering observation and ergonomic methods show, however, that manual-handling risk is not determined by weight alone. It results from the combined effects of weight, posture, frequency, horizontal reach, pickup and placement heights, vertical travel, twisting angle, grip quality, work pace, and environmental conditions. The same weight can impose markedly different loads on the lower back, shoulders and neck, lower limbs, wrists, and hands under different postures, frequencies, and environments.

Using a person–machine–environment–organization systems perspective, this document combines ergonomic methods, the Revised NIOSH Lifting Equation (RWL and LI), and the hierarchy of controls—elimination, substitution, engineering controls, administrative controls, and personal protective equipment—to establish a practical method for identifying manual heavy-load handling risks, quantifying indicators, rapidly classifying tasks, and selecting engineering improvements at manufacturing sites. It also provides worked examples, an FMEA example, an on-site observation form, and answers to frequently asked questions for safety managers, equipment managers, process engineers, and production supervisors. This document provides engineering-level risk-screening and improvement guidance; it does not constitute a medical diagnosis, occupational-disease determination, workplace-injury determination, or legal opinion. Any assessment of health effects must integrate measured site data, employee feedback, occupational-health examinations, and professional judgment.

Keywords

Manual handling; heavy-load handling; occupational-health risk; ergonomics; NIOSH Lifting Equation; RWL; LI; workplace-injury prevention; engineering controls; Pneumatic Industrial Manipulator

Key Points

Risk in manual heavy-load handling cannot be assessed from item weight alone. Weight is only a baseline exposure factor. Posture, frequency, horizontal reach, pickup and placement heights, vertical lift distance, trunk twisting, grip quality, transfer route, floor conditions, temperature and humidity, work pace, recovery time, and employee feedback collectively determine risk. Engineering improvements should first reduce unnecessary or poorly designed handling motions, then consider equipment assistance and administrative controls.

1. Scope and Boundary of Application

1.1 Applicable scenarios

This article is applicable to the risk identification and engineering improvement reference for heavy-duty handling operations that are completed manually or partially manually in manufacturing and related sites. Typical scenarios include:

- Short-distance transfer between unloading and workstations on the production line;
- workpiece picking, placing, turning and positioning during assembly;
- Packaging, palletizing, depalletizing and turnover containers handling;
- Sorting, replenishment and temporary handling in warehousing logistics;
- Temporary handling for equipment maintenance, model change and non-standard parts.

1.2 Problems not solved in this article

In order to avoid writing engineering risk assessment into a medical diagnosis or legal conclusion, this article clarifies the following boundaries:

- It does not judge whether any employee has a specific disease or diagnose individual health status;
- It does not determine whether a certain injury constitutes a work-related injury. The determination of work-related injuries should be based on local regulations, factual materials and the procedures of the competent department;
- NIOSH RWLs, LIs, or establishment rating scales are not written as mandatory legal limits; they are used for engineering screening, comparison, and improvement ranking;
- Do not cite specific provisions, limits or mandatory requirements of national standards without checking the official text. When standards are involved, only describe their methodological positioning.

Table 1: Engineering expression boundaries used in this article

Easy-to-miswrite expressions	Recommended expression	Description
Manual handling can cause lumbar disorders	Adverse handling conditions may increase low back musculoskeletal load and risk of injury	Avoid absolute causality and medical diagnosis
It is illegal to exceed a certain weight	Specific limits and compliance judgments should be based on applicable regulations, official texts of standards and corporate systems.	Avoid writing project proposals into legal conclusions
Equipment can completely replace labor	Mechanical assist equipment is one of the engineering control measures, and it still needs to match the workstation and operating process.	Avoid product promotion and absoluteness
If LI is greater than 1, you will definitely be injured.	The higher the LI, the more unfavorable the task is relative to the recommended weight	Avoid equating risk indicators with individual

Easy-to-miswrite expressions	Recommended expression	Description
	limit, and priority should be given to attention and improvement.	injury outcomes
Injuries can be completely avoided by using power assist devices	Assistance equipment can reduce some exposures, but risk indicators and employee feedback still need to be retested after introduction.	Avoid absolute statements like “zero risk”

2. Introduction: Why Risk Cannot Just Look at Weight

2.1 After automation, why does manual handling still exist?

Automation and logistics equipment can cover standardized, long-distance, high-volume handling, but often cannot fully replace short movements between workstations, at machine interfaces, or around custom tooling. Frequent changeovers, high product variety, small batches, restricted space, and temporary tasks still rely heavily on manual work. A task that appears to be “just one quick move” may involve low pickup height, extended reach, turning under load, poor grip, and high-frequency repetition.

2.2 Why traditional judgment based on weight alone is insufficient

Company safety programs often use unit weight as the primary criterion—for example, asking whether a workpiece exceeds a specified weight. This measure is intuitive and easy to apply, but does not represent actual biomechanical load. Handling the same weight close to the body at waist height and only occasionally can differ greatly from handling it while bending low, reaching far, twisting under load, or repeating continuously at high frequency. A sound engineering approach records weight together with posture, frequency, distance, height, coupling, and environmental conditions and treats handling as a work system shaped by the person, workpiece, equipment, workstation layout, and organizational work pace.

2.3 Research objectives

The goal of this article is to provide a set of executable methods for manufacturing sites: identify the main risk sources of manual handling, establish recordable and comparable evaluation indicators, use the Revised NIOSH Lifting Equation to quantify and sort projects, distinguish different improvement strategies for low-frequency handling and high-frequency handling, and provide engineering improvement paths and verification methods based on hierarchical control ideas.

3. Principal Occupational-Health Risk Categories in Manual Heavy-Load Handling

The effects of manual handling on the human body are usually manifested as increased local musculoskeletal load, fatigue accumulation and risk of sudden instability. The following content is a description of engineering risks, which means "may increase certain types of load or risk of injury" and does not constitute a medical judgment on any individual.

3.1 Lower back risks

Lower-back loading arises primarily from forward bending, holding the hands away from the body, rising under load, trunk twisting, and sudden loss of balance. When the workpiece center of gravity is far from the body or the trunk twists while rising, the lower-back muscles must generate a larger counter-moment to stabilize the body and load, which can increase fatigue, discomfort, soreness, and strain risk.

3.2 Shoulder and neck risks

When the picking and placing height exceeds the comfortable working area, or when it is necessary to lift the shoulders, shrug, reach from a distance, or place overhead, the shoulder and neck muscles need to continue to participate in stabilization and force generation. High shelves, too high work clothes, prolonged arm lifting and repeated overhead movements are all shoulder and neck loading scenarios worthy of attention.

3.3 Knee and lower limb risks

Picking up from a low level, squat lifting, handling on ramps or steps, and handling on slippery floors can increase loads on the knees, ankles, and lower-limb muscles. Frequent deep squatting, half-squatting, or turning while loaded can also increase lower-limb fatigue, instability, fall risk, and sprain risk.

3.4 Wrist and hand risks

When workpiece has no handle, smooth surface, sharp edges, shifted center of gravity or needs to clamp handling, the operator usually needs to increase the grip strength and change the wrist posture, which may increase the risk of fatigue and strain of the wrist, forearm and fingers, and increase the possibility of slipping, smashing and misplacement.

3.5 Repetitive loading and risk of chronic fatigue

High-frequency handling may not involve a heavy individual lift, but it creates high repetitive exposure and insufficient recovery. Even light units can produce cumulative fatigue when repetitions per hour are high, duration is long, and recovery intervals are short. A low-frequency heavy lift creates a different risk mechanism from the cumulative fatigue of high-frequency light-to-medium loads, so the improvement strategies should also differ.

3.6 Acute sprain and accident risk

Slips, trips, loss of center of gravity, out-of-synchronization of multiple people on the handling, passage obstacles, temporary turns, obstructed vision and height differences on the ground may all induce acute sprains, crushing, injuries or falls. Such risks are often related to environmental and organizational factors and cannot be addressed by limiting weight alone.

4. Sources of risks of manual handling ergonomics

Manual-handling risk results from interacting factors. An on-site assessment should ask not only how many kilograms are involved, but also how the load is handled, where it starts and ends, how many times per minute it is moved, how far the hands are from the body, whether bending or twisting occurs, whether the grip is secure, what the floor and environment are like, and whether the work pace allows recovery.

Table 2 Main risk sources and engineering explanations for manual handling

Source of risk	Engineering explanation
Single handling weight	Base load source. The greater the weight, the higher the force exertion and destabilization consequences typically are per rep, but weight must be interpreted in conjunction with posture and frequency.
handling frequency	Determine the number of repetitions per unit time and recovery time. Low-frequency tasks tend to be transient loads, while high-frequency tasks tend to be cumulative fatigue.
Shift cumulative weight handling	Unit weight × number of handling cycles per shift reflects total exposure intensity during the shift and is an important supplementary indicator for high-frequency tasks.
horizontal reach	The farther the hands are from the body, the greater the resistance torque required on the lower back and shoulders. Shortening horizontal distance is often a high-yield improvement.
Pick and place height (starting point/end point)	Taking objects from the ground or below the knees may increase bending and squatting; placing objects above shoulder height may increase the load on the shoulders and neck.
vertical lift distance	The greater the height difference between the starting point and the end point, the more muscle groups are continuously involved in the handling process, and the higher the risk of fatigue.
bending angle	The deeper the trunk bends forward, the greater the torque the low back bears; frequent deep bending is a typical sign of high-risk postures.
Torso twist angle	Trunk twisting under load introduces asymmetric loading and should first be reduced through a turntable, slide, or workstation-layout change.
Grip conditions	No handles, smooth, sharp edges, off-centre, flexible packaging, etc. increase grip strength and poor wrist posture while increasing the risk of falling.
workpiece size, shape and center of gravity	Large volumes, obstructed vision, shifted center of gravity, liquid sloshing and flexible materials can reduce controllability.
handling route	Routes that are long, detoured, have steps, ramps, or cross-traffic can increase physical exertion and exposure to falls and collisions.
Ground and working environment	Slippery, oily dirt, insufficient lighting, high temperature, damp heat, noise, dust and limited space will amplify the handling risk.
Work Pace and Recovery Time	Equipment tempo, order pressure, lack of buffers and micro-breaks can cause fatigue to continue to build up during a shift.

The difference between low frequency and high frequency handling

The main risks of low-frequency, short-distance, and sporadic handling often come from the posture, grip, weight, and imbalance consequences of a single movement; the main risks of high-frequency, repetitive, and continuous handling come from exposure per unit time, insufficient recovery, and accumulation of fatigue. Therefore, low-frequency tasks should focus on optimizing single movements, and high-frequency tasks should focus on reducing repeated exposure, improving tempo, and evaluating mechanical assistance or delivery options.

5. On-site risk assessment index system

5.1 Basic exposure indicators

In order to make handling risks recordable, comparable, and traceable, enterprises can establish basic exposure indicators. It is recommended that data be obtained through on-site observation, video sampling, tape measurements, weighing, shift recording and employee feedback.

Table 3 Basic indicators for manual handling on-site evaluation

indicator	Unit / Classification	Recording method	risk significance
Unit Weight	kg	Weighing or bill of materials	base load
handling times per minute / hour	times/min, times/h	Observation counting or video analysis	Repeated Exposure and Recovery Time
Shift handling total number of times	times/shift	Shift records	Duplicate exposure during shifts
Shift cumulative weight handling	kg/class	Unit Weight × Total Number of Cycles	Cumulative load
Horizontal handling distance	m	route measurement	Physical exertion and exposure to falls
Hand horizontal distance H	cm	The horizontal distance from the hand to the midpoint of the two ankles	Back moment
starting height	cm	Tape measure	Bending/squatting signal
finish height	cm	Tape measure	Shoulder and Neck/Overhead Signal
Vertical lift distance D	cm	End height − Starting height	Continuous exertion and fatigue
Trunk twist angle A	°	Video estimation / on-site observation	asymmetric load
Grip conditions	good/average/poor	Handle, non-slip, center of gravity, finger space	Wrist load and risk of falling
subjective fatigue score	0–10	Questionnaire before/during/after class	Fatigue Cumulative Cues
Discomfort feedback	location + degree	Anonymous feedback/health management records	Continuous improvement leads
environmental risks	Grading	Slippery, high temperature, lighting, obstacles	Risk amplifying factors
Are there assistive devices?	Yes / No	On-site confirmation	Current status of engineering controls

5.2 Cumulative handling exposure

In high-frequency handling, unit weight alone does not represent exposure over the shift. The following two simple indicators may be used for preliminary screening:

Calculation formula

Shift cumulative handling weight: $M_{total} = m \times N$

Hourly accumulated handling weight: $M_{hour} = m \times n_{hour}$

where m is unit weight (kg), N is the total number of handling cycles per shift, and n_{hour} is the number of cycles per hour. These indicators compare workload intensity across workstations; they are not medical diagnostic criteria or legal limits.

5.3 Comprehensive risk screening score

In the absence of complete NIOSH data or limited on-site measurement conditions, a 1-5 point scale can be used for rapid screening and for internal risk ranking within the enterprise. The rating table should be revised regularly based on industry characteristics and historical data.

Table 4. Comprehensive risk screening score recommendations

Rating	risk level	Description
1	low	Small weight, low frequency, good posture, stable environment, no obvious fatigue feedback
2	lower	There are a few adverse factors, but they last for a short time and personnel can recover.
3	in	Significant disadvantage in at least one of weight, frequency, form, distance or grip
4	higher	Multiple factors are superimposed, and there are feedbacks from fatigue, discomfort or minor incidents.
5	high	Heavy weight or high-frequency continuous, while there are bending and twisting, long-distance reaching, poor environment or abnormal event records

Example weight

Risk Score = Weight score × 0.25 + Frequency score × 0.20 + Posture score × 0.20 + Distance/height score × 0.15 + Grip score × 0.10 + Environment score × 0.05 + Subjective feedback score × 0.05. This weight is only used for preliminary screening within the enterprise and does not replace professional ergonomics evaluation, occupational health evaluation or medical judgment.

6. Careful interpretation of relevant standards and reference systems

This article refers to several domestic and foreign ergonomics and occupational safety and health materials at the method level. Special explanation is needed: The specific provisions, scope of application, limits and current status of the standard should be based on the official text of the standard and the applicable scenarios of the enterprise. This article does not cite or fabricate specific mandatory terms or limits.

Table 5: Method positioning of standards and reference systems

Standard/Reference System	How to use it in this article
GB/T 16251-2023 "Ergonomics Principles for Work System Design"	As the general outline of work system design, human capabilities, loads, health risks, system performance and sustainable operations are considered from the perspective of "man-machine-environment-organization".
GB/T 10000-2023 "Human Dimensions of Chinese Adults"	It can be used as a human body size reference for workstation height, reach distance, operating space, passage and access height; specific values need to be checked with the official text.
GB/T 14775-1993 "General Ergonomics Requirements for Manipulators"	May inform the design of control buttons, handles, pedals, control directions, legibility, and ease of operation to reduce secondary risks during equipment use.
GB/T 18978 series "Human-system interaction ergonomics"	Addresses human–machine interaction, displays, input, and human-centered design. Where equipment includes a display, alarm interface, or data-acquisition terminal, it may provide an interaction-ergonomics reference.
ISO 11228 handmade handling series	Provides background on international methods for evaluating manual lifting, carrying, pushing/pulling, and repetitive low-load work. Limits should not be quoted without verification.
NIOSH Revised Lifting Equation （RNLE）	Suitable for analyzing two-hand lift/placement tasks, converting weight, horizontal distance, vertical height, lift distance, twist, frequency and grip conditions to RWL and LI.
Occupational health related GBZ / GBZ/T standards	Where workplace physical factors, work intensity, heat, noise, dust, or occupational-health management are involved, an occupational-hygiene professional should assess the applicable standards.

Standard citation principles
Corporate Resource Center articles may cite standard titles and describe methodological approaches, but should not state specific clause numbers, limits, or compliance conclusions unless the official text has been verified. If material will later be used for tendering, acceptance, factory audits, or legal purposes, verify the standard version and conduct a separate compliance review.

7. Engineering Interpretation of the Revised NIOSH Lifting Equation

7.1 Basic formulas

The Revised NIOSH Lifting Equation (RNLE) uses multiplier factors to adjust the load constant under ideal conditions to a Recommended Weight Limit for a specific task. A common expression is:

RNLE formula

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

LI = Load / RWL (Load is the actual handling weight)

Table 6 Revised NIOSH Lifting Equation symbol description

symbol	meaning	Engineering explanation
RWL	Recommended Weight Limit, recommended weight limit	Engineering reference weights under specific operating conditions, used for task comparison and improvement ranking, are not legal limits, nor are they a guarantee of individual safety.
LC	Load Constant, load constant	The baseline load for ideal two-hand lift conditions is taken as 23 kg (approximately 51 lb) in the equation.
HM	Horizontal Multiplier, horizontal distance factor	The farther the hand is from the body, the smaller the HM; reaching at long distances significantly reduces RWL.
VM	Vertical Multiplier, vertical height factor	The further the starting height deviates from the comfort zone, the smaller the VM is.
DM	Distance Multiplier, vertical displacement factor	The larger the lift distance, the DM tends to decrease.
AM	Asymmetric Multiplier, asymmetric factor	The larger the trunk-twisting angle, the smaller the AM.
FM	Frequency Multiplier, frequency factor	The greater the handling frequency, the longer the duration, and the less recovery time available, the smaller the FM.
CM	Coupling Multiplier (grip-quality factor)	The poorer the grip quality, the smaller the CM.
LI	Lifting Index	Ratio of actual weight to RWL. The higher the LI, the more unfavorable the task is compared to the recommended conditions, and the more priority should be paid to attention and improvement. LI is not a medical diagnosis.

7.2 Engineering significance of RWL and LI

RWL is an engineering output used for mission design and risk comparison. Each multiplier factor is usually no greater than 1; when a condition deviates from the ideal state, such as too large a horizontal distance, too low a starting point, a high frequency, a large twist angle, or a poor grip, the corresponding factor is reduced and the RWL is reduced accordingly. RWL is not a legal limit and LI is not a medical diagnostic indicator. LI is the ratio of actual weight to RWL. The higher the LI, the more unfavorable the task is relative to the recommended conditions, and the more priority should be given to engineering improvements.

In workplace use, LI should not be reduced to an individual prediction of whether an injury will occur. A more appropriate approach is to use LI with employee feedback, fatigue observations, accident and abnormal-event records, workstation work pace, and environmental factors to prioritize workstations, compare solutions, and reassess before and after improvement.

7.3 Applicable boundaries

Revised NIOSH Lifting Equation is mainly suitable for standing, two-handed, stable lifting and placing tasks. The following situations should not be applied directly and should be used with caution and in combination with other evaluation methods and professional judgment:

- Hold handling with one hand or hold handling;
- Multi-person collaboration handling;
- Pushing, pulling, and dragging operations;
- handling in sitting, kneeling or severely restricted space;
- handling on ladders, steps or unstable support surfaces;
- Extreme high temperatures, low temperatures or other special environments;
- Loads with sudden impact, unstable living body or violent shaking of liquid.

8. Worked Examples and Interpretation of Typical Conditions

8.1 Task Description

The following examples are used to demonstrate calculation ideas and do not represent any company's actual limits, nor are they intended for medical or legal judgment. Assume that a workstation needs to move 25 kg workpiece from the low pallet to the workbench. The on-site observation data is as follows:

Table 7. Example Task Parameters

parameters	Example value
Unit weight Load	25 kg
Hand horizontal distance H	45 cm
Starting height V	50 cm
Vertical lift distance D	70 cm
Trunk twist angle A	45°
handling frequency F	2 times/min
duration	2 h
Grip conditions	Average

8.2 Calculation process

The formal assessment should determine each multiplier factor based on on-site measured data and NIOSH official tables or calculation tools. To demonstrate the calculation idea, the following approximate example values are used here (the frequency factor is related to the duration interval, and the example value is based on a more conservative interval):

Table 8: Example factor values (for demonstration only)

factor	Example value	Main influencing factors
LC	23 kg	Equation Base Load Constant
HM	0.56	Horizontal distance 45 cm, hands farther away from the body
VM	0.93	Starting height 50 cm, below comfort zone
DM	0.88	Vertical lift 70 cm
AM	0.86	Torso twist 45°
FM	0.65	2 times/min Continuous operation, insufficient recovery
CM	0.95	Average grip conditions

Calculation results (example)

RWL ≈ 23 × 0.56 × 0.93 × 0.88 × 0.86 × 0.65 × 0.95 ≈ 5.6 kg

LI = 25 / 5.6 ≈ 4.5

The above factor values and results are examples only. Formal evaluation should be based on on-site measurements, official NIOSH forms/formulas, and professional judgment.

8.3 Engineering Interpretation

In this example, actual handled weight is substantially greater than the calculated Recommended Weight Limit, and LI is well above 1, indicating that the task should receive priority in engineering assessment. Importantly, the primary factors reducing RWL are not the weight itself, but horizontal distance and frequency. The low horizontal multiplier indicates that the hands are far from the body, increasing the moment on the lower back; the low frequency multiplier indicates high repetitive exposure and insufficient recovery; and the asymmetry multiplier identifies an adverse effect from twisting under load. The result is not a medical or legal conclusion; it supports prioritization of engineering improvements.

8.4 Improvement Directions

- Reduce unit weight, use smaller packages, or divide handling into batches;
- Raise the pickup point to approximately waist height, for example by using a lift table;
- Shorten the horizontal reaching distance and bring workpiece closer to the body;
- Reduce trunk twisting under load by using a turntable, slide, or forward-facing layout;
- Improve gripping conditions by adding handles, tooling or trays;
- Reduce the frequency of handling and increase buffering and rotation;
- In high-frequency or continuous operation scenarios, evaluate engineering control measures such as lifts, conveyor lines, Pneumatic Industrial Manipulator, vacuum lifters, or counterbalance cranes.

9. Comparison between low frequency handling and high frequency handling

The risk mechanisms and improvement priorities are different for the same weight under different frequency, posture and layout conditions. This is a direct reflection that the evaluation of manual handling cannot only look at weight.

Table 9 Comparison of low frequency and high frequency handling (taking 25 kg as an example)

Contrast Dimensions	Scenario A: low frequency, close to the body, occasional handling	Scenario B: High frequency, long-distance reaching, bending and twisting handling
weight	25 kg	25 kg
posture/distance	Pickup and placement at waist height, close to the body, with little or no twisting	Fetching objects from a low position, reaching for long distances, and twisting with weight
Frequency	Occasionally, such as several times per shift	High frequency continuous, such as more than 2 times/min
Main risk mechanisms	Single instantaneous load and instability consequences	Accumulated fatigue, insufficient recovery, and superimposed single high load
Typical signal	Some movements are difficult and there are occasional dangers	Fatigue, persistent discomfort feedback, and decreased efficiency during class
Improvement focus	Optimize single posture, gripping conditions and pick and place height	Reduce repeated exposure, relocate workstations, evaluate conveying or mechanical assistance

10. Manual handling risk level rapid grading table

The table below can be used for quick on-site grading. The grading results are used for internal sorting and improvement priority judgment of the enterprise, and are not statutory risk levels. Enterprises can adjust the description based on industry, working population, historical events and occupational health management requirements.

Table 10: Manual handling risk level quick grading table (low/medium/high/very high)

risk factors	low	in	high	very high
Single weight	Lighter, stable control	Medium, requires significant effort	Heavy or close to the load capacity limit	Very heavy, off-centre, or requiring some effort to complete the task
handling frequency	Occasionally	periodic repetition	High frequency, less recovery	High frequency continuous, almost no recovery
handling distance	Short distance, clear route	medium distance	long distance or detour	Long distances, complex routes, and cross logistics
Pick and place height	near waist	below the knees or above the chest	Pickup from floor level or placement above shoulder height	Pick up items from the ground and place them overhead
Reach horizontally	close to body	medium reach	reach out from a distance	Reaching from a distance and holding it continuously
Stooped posture	Basically upright	bend down occasionally	Frequent bending	Frequently bend deeply and stand up with weight
twisting action	None or very little	Turn around occasionally	Twisting with weight	Twisting of waist when bearing weight and occurs frequently
Grip conditions	Good handle, non-slip	Average grip	Handleless or smooth	No handles and sharp edges, off-centre or flexible
ground environment	Smooth and dry	local obstruction	Slippery, slopes or steps	Multiple unfavorable environments superimpose
Temperature and humidity lighting	normal	Slightly uncomfortable	High temperature, humidity or insufficient lighting	Extreme temperature and humidity combined with insufficient lighting
fatigue feedback	No obvious fatigue	Fatigue after work	Obvious fatigue during class	Sustained high fatigue and impact on movement quality
Discomfort feedback	None	Occasional individual feedback	Multiple people or repeated feedback	Continuous feedback with abnormal event records

11. Project improvement path and hierarchical control

11.1 Hierarchical control principle

ergonomics improvement should follow the hierarchical control idea of "elimination-replacement-engineering control-management control-individual protection". The priority is to eliminate or reduce unreasonable handling actions, followed by substitution and engineering control, supplemented by management control and personal protection. Personal protective equipment can only reduce part of the exposure or accident consequences, and cannot replace workstation design, equipment assistance and process improvement.

Table 11 handling risk control level

Hierarchy	Typical measures	Description
eliminate	Eliminate unnecessary manual handling, low-level pickup/placement, or turning under load	The highest priority and should be implemented in the process and layout design stages
substitute	Small packaging, batches, standard containers, pre-packed pallets, pre-positioned tooling	Reduce single load and job variability
engineering controls	Lifting platform, scissor lift, turntable, drum line, conveyor line, pneumatic balancer, Pneumatic Industrial Manipulator, vacuum lifter, AGV, special tooling, turnover pallet, workstation rearrangement	Modification of exposure conditions through equipment, tooling, or layout
management control	Job rotation, work-pace optimization, recovery intervals, work instructions, training, and inspections	Rely on execution and supervision and cannot alone replace engineering controls
personal protection	Non-slip shoes, gloves, protective gear, heatstroke prevention and cooling supplies	Auxiliary measures focus on adaptation and correct use and cannot replace engineering improvements.

11.2 Key points for implementation of engineering control

- Engineering controls should prioritize the deployment of high-risk workstations, prioritizing based on RWL/LI, cumulative exposure, risk classification and employee feedback;
- Equipment is not a one-size-fits-all solution. Before importing, you should first evaluate whether the problem can be solved through elimination, substitution, or rearrangement of workstations;
- Equipment selection must consider load, working radius, stroke, tooling type, air/electrical supply conditions, space, work pace, and protective functions as an integrated system;
- Personal protection cannot replace engineering improvements, but can only be used as a supplementary measure for residual risks.

12. The intervention boundary of mechanical power-assisted equipment

Mechanical assist equipment—including lift tables, Pneumatic Industrial Manipulators, Vacuum Lifters, and Pneumatic Balancers—is one part of engineering controls for manual handling, not a substitute for every manual action. It carries the primary load and supports stability and positioning so the operator can work with a more comfortable posture, controlled work pace, and lower physical load.

12.1 Situations suitable for assessment intervention

- High unit weight, or a need to hold, position, or turn the load for an extended period;
- handling is repeated frequently, employees have insufficient recovery, and the cumulative exposure during the shift is high;
- The height difference between picking and placing is large, requiring frequent bending, shoulder lifting or overhead operations;
- workpiece has no handle, is eccentric, easily damaged, has a smooth surface, or requires special tooling;
- Turning under load, extended reach, constrained posture, or spatial interference.

12.2 Situations not suitable or requiring careful evaluation

- Workstations with extremely high cycle times and unable to accept equipment operation time;
- Workstations where varieties are frequently switched and material forms vary greatly, making it difficult for tooling to cover;
- Areas with narrow space, serious traffic/logistics interference, and restricted equipment layout;
- Operations that require complex judgment, fine touch, or frequent abnormal handling;
- For workstations that have not yet completed process rearrangement and tooling verification, it is advisable to change the process first and then evaluate the equipment.

12.3 Possible secondary risks caused by equipment

The mechanical power-assisted equipment itself may also introduce new risk points. During selection and acceptance, "whether it can save effort" and "whether it is easy to operate safely, stably and intuitively" should be evaluated at the same time. Typical secondary risks include: unreasonable handle position leading to inconvenient operation; unintuitive button/control logic or unclear feedback; inaccessible emergency stop; incompatibility between tooling and workpiece leading to unstable clamping; insufficient release logic leading to mistaken release; insufficient air loss/power-off protection and heavy-load sinking control; the equipment body or load blocks the line of sight; and spatial interference with peripheral equipment, traffic and passages.

12.4 Retesting and closed-loop after introduction

A more reliable implementation path is: first identify high-risk workstations, and then use RWL/LI, cumulative exposure and risk classification to determine improvement priorities; after the equipment is put into operation, retest the handling posture, frequency, employee fatigue feedback and abnormal events to confirm that the risk indicators have actually declined and no new adverse actions have been introduced, forming a closed loop of assessment-improvement-verification.

13. Comparison before and after improvement of typical problems

The following table summarizes improvement directions for common manual-handling problems and may serve as a starting point for workstation-improvement discussions. Select specific measures using measured workstation data, work pace, and investment constraints.

Table 12 Comparison before and after improvement of typical handling problems

Typical issues before improvement	Improvement Direction	Project points	expected effect
Fetching objects from the ground, frequently bending over deeply	Lifting pallet / scissor lift table	Keep pickup height near waist level and raise the load as items are removed	Reduce forward trunk bending and deep squatting
Reach and place from a distance	Workstation Layout Redesign	Shorten the depth of the table and bring workpiece closer to your body	Reduce back torque
Turn around and release the material after loading	Turntable or linear flow arrangement	Change to forward pick and place, add turntable, slide table or roller line	Reduce asymmetric loads
High frequency repeat handling	Conveyor line or mechanical assistance	Add conveyors and buffer zones; assess Pneumatic Industrial Manipulators or Pneumatic Balancers; optimize work pace and job rotation	Reduce repeated exposure and fatigue accumulation
No handle, difficult to grasp	Special tooling or pallet	Add handles, tooling, turnover boxes or non-slip surfaces to mark the center of gravity	Reduces wrist load and risk of falling
The floor is slippery and oily	Anti-slip treatment and cleaning system	Anti-slip floor, drainage design, establish cleaning system inspection	Reduce the risk of slips and instability
High temperature environment handling	Environmental and organizational improvement	Ventilation, heat insulation barriers, off-peak work, rest and hydration	Improve continuous operation ability
workpiece eccentric, unknown center of gravity	Center of gravity mark and special bracket	Mark the center of gravity position and design the limit bracket or tooling	Improve the controllability of handling
Route detours and access obstacles	Logistics line re-planning	Optimize routes, position management, and reduce intersections	Reduce fall and collision exposure

14. FMEA Risk Analysis Example

To support workstation risk ranking, FMEA (Failure Mode and Effects Analysis) methods can be used. S is severity, O is occurrence, and D is detectability, all rated on a scale of 1-10, RPN = S × O × D. The scores in the following table are examples. FMEA scores are only used for internal risk ranking and improvement priority discussions within the enterprise. They do not represent legal conclusions and should be revised regularly based on actual on-site conditions.

Table 13: Manual handling FMEA risk analysis example

serial number	Failure modes/risk scenarios	possible consequences	main reason	S	O	D	RPN	Improvement measures
1	Bending low to lift a heavy load	Lower back discomfort and increased risk of strain	The pallet is too low and there is no lifting device	8	7	5	280	Lifting platform to increase the height of picking materials
2	Turn around and release the material after loading	Increased asymmetric load on the low back	Poor layout or misaligned pickup and placement directions	8	6	5	240	Forward pick-and-place, turntable/sliding table
3	High frequency repeat handling	Fatigue accumulation and movement deformation	Fast pace, no recovery time	7	8	5	280	Mechanical assistance, transportation, job rotation
4	No handle or difficulty gripping	Excessive force on the wrist and slipping	workpiece shape is not suitable for gripping	6	7	6	252	Special tooling, handle, tray
5	Slippery floor handling	Slip, sprain, bruise	Oil stains, water stains, insufficient cleaning	9	5	4	180	Anti-slip floor, drainage, cleaning inspection
6	High temperature environment handling	Fatigue accelerates and stability decreases	Poor ventilation and concentrated heat sources	7	6	5	210	Ventilation, cooling, heat insulation, rest and hydration
7	Obstructed view handling	Collision, fall, misplacement	workpiece is too large or stacked too high	8	5	5	200	Reduce stacking height and replace carts/pallets
8	Multiplayer handling out of sync	sprain, pinch, drop	Lack of passwords and collaboration specifications	8	4	5	160	Work instructions, synchronization passwords, special tools
9	workpieceeccentrichandling	Instability, sudden increase in lower-back and wrist load, or load drop	Invisible center of gravity, no markings, no brackets	7	6	6	252	Center of gravity mark, special bracket, mechanical assistance when necessary
10	Auxiliary equipment tooling is not suitable	Unstable clamping, mistaken release, secondary handling	selection does not cover the workpiece pedigree and has not been verified by tooling.	8	4	6	192	selection evaluation, tooling trial installation verification, operation training and inspection

15. Manual handling on-site operation observation form

The table below can be used directly for field recording, along with tape measures, scales, timing and video sampling. The examples are for reference only.

Table 14: On-site risk assessment form for manual handling of heavy loads

Project	Record content/unit	Fill in example
Enterprise/Workshop		Example: General assembly workshop
Workstation name		Example: Packaging and unloading station
Assessment date		
evaluator		
work shift	Day shift / night shift	day shift
Material name		Metal box
Unit Weight	kg	25
handling times per hour	times/h	120
Shift handling total number of times	times/shift	800
Shift cumulative weight	kg/class	20000
handling starting height	cm	40
handling end height	cm	90
vertical lift distance	cm	50
horizontal reach	cm	45
handling horizontal distance	m	3
Whether to bend over/bending angle	yes/no,°	Yes, about 45
Whether to twist/twist angle	yes/no,°	Yes, about 45
Is it above shoulder height?	Yes / No	No
Grip conditions	good/average/poor	Average
Is workpiece eccentric?	Yes / No	Yes
Whether to block sight	Yes / No	No
Ground conditions	Dry / Slippery / Slope / Steps	Partially slippery
lighting conditions	good/average/deficient	Average
Temperature and humidity environment	Normal/High Temperature/Moist Heat	high temperature
Are there assistive devices?	Yes / No	None
subjective fatigue score	0–10	7

Project	Record content/unit	Fill in example
Discomfort feedback area	Lower Back / Shoulder / Knee / Wrist / Other	Lower back and shoulders
Past unusual events	sprain/slip/fall/none	There has been a slip
NIOSH RWL	kg	To be calculated
NIOSH LI		To be calculated
Preliminary risk level	low / medium / high / very high	high
Prioritize improvement suggestions		Lifting table + turntable + frequency reduction

16. Frequently Asked Questions (FAQ)

Q1: Does the risk of manual handling only depend on weight?

No. Weight is just the base exposure factor. Load levels can vary greatly for the same weight under different postures, frequencies, horizontal reach distances, pick and place heights, gripping conditions and environments. On-site assessments should also document weight, frequency, distance, height, posture, grip, environment and employee feedback.

Q2: Is the 25 kg manual handling necessarily dangerous?

Not necessarily, nor does the opposite conclusion—that it is always safe—follow. A 25 kg load handled occasionally at waist height and close to the body presents a markedly different risk from the same load handled low, at extended reach, with trunk twisting, and continuously at high frequency. The assessment must use complete task parameters and an engineering evaluation, not one weight value.

Q3: What does NIOSH LI greater than 1 mean?

LI greater than 1 means that actual handled weight exceeds the Recommended Weight Limit (RWL) calculated for that task, indicating less favorable conditions relative to the recommendation. Higher LI values warrant higher priority for attention and improvement. LI is an engineering screening and prioritization indicator; it is not a medical diagnosis and does not establish a legal violation.

Q4: Is RWL the legal limit?

No. RWL is the engineering reference weight calculated under specific operating conditions by the Revised NIOSH Lifting Equation and is used for task comparison and improvement ranking. Compliance judgments should be based on applicable regulations, official texts of standards and corporate systems.

Q5: Why is the high-frequency handling more worthy of attention than the occasional handling?

High-frequency handling creates high repetitive exposure and insufficient recovery. Even when unit weight is modest, fatigue can accumulate throughout the shift and may degrade movement quality and stability. Occasional handling is dominated by the instantaneous load from an individual event, whereas high-frequency handling is dominated by cumulative fatigue; their assessment indicators and improvement strategies should therefore be defined separately.

Q6: Can Pneumatic Industrial Manipulator completely replace labor?

No. A Pneumatic Industrial Manipulator is one type of engineering control. It primarily supports the load and improves stability and positioning while the operator continues to guide the task. It is suitable for high-load, high-frequency, or ergonomically unfavorable workstations, but must be assessed for load, radius, stroke, tooling, space, and work pace. After introduction, risk indicators and employee feedback should be reassessed.

Q7: What scenarios are suitable for considering a vacuum lifter?

Vacuum Lifters are generally suitable for workpieces with relatively flat, reasonably airtight surfaces that can withstand vacuum holding force, such as panels, enclosures, bagged materials, and some drums. Porous, air-permeable, heavily contaminated, high-temperature, or extremely irregular workpieces require suction-cup selection and an on-site trial lift, together with safety functions such as loss-of-air protection.

Q8: When improving workstations, should we buy equipment first or change the process first?

It is recommended to evaluate and change the process first. According to the hierarchical control idea, we should first see whether unnecessary handling can be eliminated and exposure can be reduced through layout adjustment and containerization; on this basis, equipment plans for workstations that are still high risk should be re-evaluated. If you directly purchase equipment without changing the process, the equipment may be idle, the tooling may not be suitable, or secondary risks may be introduced.

Q9: If employees report backache, can it be directly judged as an occupational disease?

No. Employee reports of fatigue and discomfort are important engineering-improvement signals and indicate that the workstation should be reviewed and improved as a priority. Occupational-disease diagnosis, however, follows statutory procedures and must be made by qualified institutions using occupational-health examinations, exposure history, and medical judgment. The company's role is to document feedback, investigate task conditions, and implement improvements—not make its own medical conclusion.

Q10: How to verify the effect after improvement?

It is recommended to use the same set of indicators for retesting before and after improvement: RWL/LI, handling frequency, cumulative exposure, posture observation (bending, twisting, reaching distance), subjective fatigue score, discomfort feedback and abnormal event records. The closed loop of improvement can be considered completed only when the indicators actually drop, employee feedback improves, and no new adverse actions are introduced.

17. Conclusion

1. Manual heavy-load handling risk is cumulative and multifactorial and cannot be determined from item weight alone. Posture, frequency, horizontal distance, pickup and placement heights, vertical travel, twisting, grip quality, work pace, and environmental factors collectively determine the risk level.

2. Risks for the low back, shoulders and neck, knees and lower limbs, wrists and hands, and fatigue are usually related to weight, horizontal reaching distance, pick-and-place height, twist angle, frequency, and grasping conditions; bending, twisting, and long-distance

reaching are generally more detrimental than close-to-body, symmetrical, and neutral postures.

3. The risk mechanisms of low-frequency short-distance handling and high-frequency repeated handling are different: the former is biased towards a single instantaneous load, while the latter is biased towards cumulative exposure and insufficient recovery. Evaluation indicators and improvement strategies should be formulated separately.
4. The Revised NIOSH Lifting Equation provides a relatively clear engineering quantification method for comparing workstations and improvement options, but its applicability limits must be understood. RWL is not a legal limit, and LI is not a medical diagnostic indicator.
5. Engineering improvement should follow the priority of "elimination - substitution - engineering control - management control - personal protection", first reduce unreasonable handling actions, and then consider equipment assistance; relying solely on training and personal protection cannot replace engineering improvement.
6. Mechanical assist equipment—including lift tables, Pneumatic Industrial Manipulators, Vacuum Lifters, and Pneumatic Balancers—is one type of engineering control. Deployment should be prioritized for high-risk workstations, improvement should be verified by reassessment and employee feedback, and potential secondary risks must also be considered.
7. On-site evaluation should be combined with employee feedback, occupational health inspection, abnormal event records, fatigue observation and professional judgment to avoid simply equating engineering evaluation with medical diagnosis or legal conclusion.
8. This engineering research document does not constitute a medical diagnosis, occupational-disease determination, workplace-injury determination, or legal opinion.

Disclaimer

Disclaimer
This article is enterprise engineering research data. The formulas, calculation examples, scores, tables and improvement suggestions listed are only for manufacturing site risk identification, engineering screening and improvement ideas reference, and do not constitute medical diagnosis, occupational disease judgment, work-related injury identification, legal opinion or mandatory standard interpretation. Content involving national standards, industry standards, occupational health evaluation and specific limits should be based on official standard texts, on-site measured data and opinions of professional institutions.

Appendix: Ergonomic Improvement Recommendations for Material-Handling Workstations

risk issues	Observe performance	Improvement goals	Engineering improvement measures	Management improvement measures	expected effect
Excessive Unit Weight	handling is difficult and needs help	Reduce single load	Packaging, standard containers, mechanical assistance	Limited to single person handling, evaluation rotation	Reduce load on lower back and shoulders
Low-level retrieval	Frequent bending	Increase the picking height	Lifting pallet, scissor platform	Material stacking height specifications	Reduce lumbar forward bend
Place it high	Lift your shoulders and raise your arms	Control working height	Lower shelves and use lifts	Specify maximum stacking height	Reduce shoulder and neck load
reach out from a distance	Keep hands far away from body	shorten horizontal distance	Workstation Layout Redesign and Slide	Material first in first out optimization	Reduce back torque
Turn around with weight	Twist and place after lifting	Change to forward handling	Turntable, drum line, U-shaped station	Adjust job order	Reduce asymmetric loads
High frequency handling	Fast pace, insufficient recovery	Reduce repeated exposure	Conveyor, Pneumatic Industrial Manipulator, or Pneumatic Balancer	Work rotation, micro breaks	Reduce fatigue accumulation
Poor grip	No handles, easy to slide	Improve grip	Special tooling, handle, tray	Glove fit check	Reduces wrist and slip risk
access barrier	detour, avoid	Shorten and stabilize routes	Logistics line re-planning	Setting management and cleaning	Reduce risk of falls and collisions
The ground is slippery	Oil stains, water stains	Improve friction and drainage	Anti-slip floors and drainage channels	Cleaning inspection System	Reduce the risk of slips and falls
High temperature environment	Sweating and fatigue quickly	Reduce heat load	Ventilation, insulation, local cooling	Rest, rehydrate, and work during off-peak hours	Improve continuous operation ability
Insufficient information	Not sure about risk level	Visual management	Data dashboard, risk identification	Training and feedback mechanism	Improve risk identification capabilities
Lack of continuous evaluation	No one will review after improvement	Establish a closed loop	Regularly retest RWL / LI	Regular ergonomics review	Establish a continuous improvement mechanism

References and Standards Index

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6. National Standard Information Public Service Platform: GB/T 16251-2023 "Ergonomics Principles for Work System Design".
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8. National Standard Information Public Service Platform: GB/T 14775-1993 "General Ergonomics Requirements for Manipulators".
9. National Standard Information Public Service Platform: GB/T 18978 series of "Human-System Interaction Ergonomics" related standards.

Note: The above information is used to illustrate the source and positioning of the method. When citing specific provisions, limits or compliance requirements of any standard, the official text and currently valid version of the standard shall prevail.