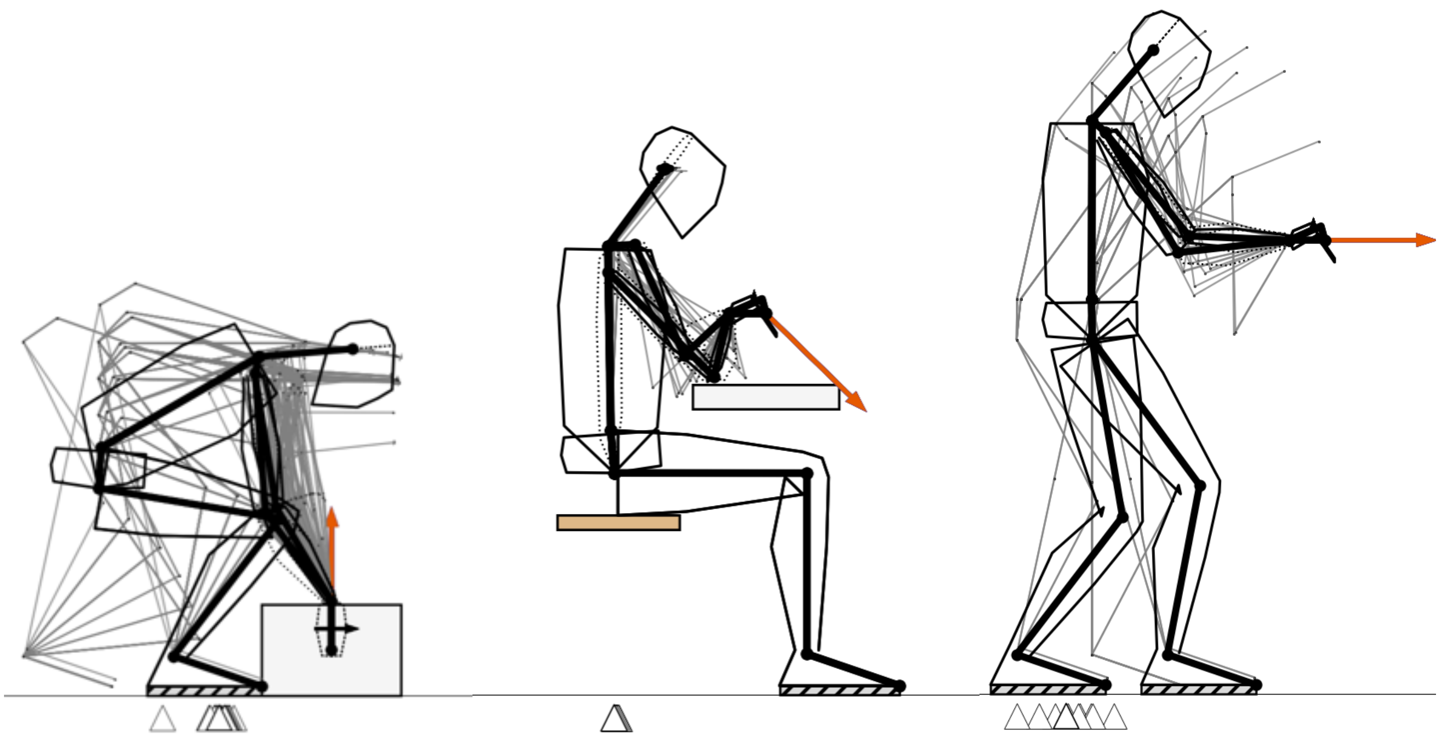
Work(s)

User Manual

Version 1.14

November 10, 2025



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Introduction

Work(s) Ergo Inc.™ is dedicated to producing task analysis software that is easy to use, while utilizing and fully integrating the most valid, science-based ergonomics assessment tools currently available. We believe that ergonomics must start to finally embrace the variability in task performance that we know exists (and is likely beneficial) both within and between workers.

Work(s)™ is a Software-as-a-Service (SaaS) application that represents the next quantum leap in the evolution of ergonomics assessment tools. Most current computerized ergonomics task analyses quantify work-related musculoskeletal disorders (WMSD) risk (1) from a single, user-defined posture, (2) often with outdated (and even unvalidated) analysis methods, and (3) require the user to integrate results obtained across the different metrics and methods.

Work(s) is unique because it assesses the full range of feasible postures for a task and integrates every assessment using the best ergonomics tools currently available to practitioners. We do this in the following ways for each task:

1) **Establish the full range of feasible postures**: Designed to assess a wide range of task types, Work(s) does not assume there is one posture but, instead, using our InteliPose™ method it determines the full variety of postures that don't exceed joint range of motion, stability, and barrier constraints. No posturing is required by the user, and the inputs are simple, familiar, and easy to obtain.
2) **Perform ergonomics assessments on each posture**: For each of the postures determined (often thousands), Work(s) performs analyses with a full suite of the best existing, science-based ergonomics assessment tools.
3) **Integrate all assessments**: While each analysis tool has its own unique outputs, we convert the output from each into a common Demand/Capacity Ratio so the results can be fully integrated across assessment tools and easily interpreted, including the ability to combine subtasks to assess complex jobs.
4) **Export a detailed Excel report**: For each task assessment, all inputs, outputs, Demand/Capacity Ratios, and graphics are combined in an Excel report that can be exported to your computer. None of your task data are saved on our servers.

Caution

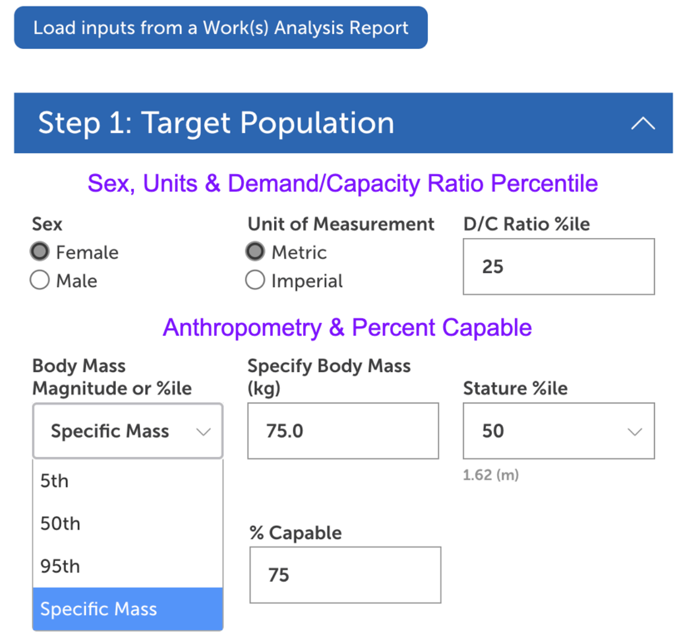
Work(s) should not be used as the sole determinant of the risk of WMSDs. The results from Work(s) should be combined with professional judgement, worker feedback, injury statistics and other criteria to evaluate occupational tasks. Before using Work(s), please read the Terms of Use at the beginning of this manual.

Getting Started

Work(s) can be accessed from the Work(s) Ergo Inc. home page by clicking "Work(s) Software" on the menu bar to get to the Work(s) software landing page. Use the green "Log in to Work(s)™" button to access the Login. Once logged in, you can go directly to the software with this link, and that can be bookmarked. You will need a Work(s) account, Userid and password to access the software. If you have not obtained a license yet, please contact Work(s) Ergo at info@worksergo.com.

Input Interface

The Work(s) input interface sets the manikin anthropometry, task type, frequency, effective duration, grip/pinch types, hand orientations, force magnitudes & directions, and hand locations relative to the middle of the ankles. The user can also input the dimensions and locations of one or two barriers, set constraints for trunk and leg postures, indicate if there is body bracing, set if an above-shoulder correction will be used, and establish where the eyes will gaze. The inputs are done in the seven steps outlined below.



Load Inputs from a Work(s) Analysis Report

Each analysis results in a Work(s) Report Excel file summarizing all the inputs and outputs. This will be explained in more detail later. Previously saved Report files made after July 28, 2023 can be opened to populate all the Input fields.

Step 1: Target Population

Sex: Select a female or male manikin and capacities for analysis.

Unit of Measurement: Select metric or imperial units.

Demand/Capacity Ratio Percentile: The Demand/Capacity Ratio (ie. “D/C Ratio” or “DCR”) is simply the demand of the task relative to the assumed capacity to meet that demand, and it provides a unitless measure of WMSD risk based on the outputs from each of the ergonomics assessment tools used in Work(s). The DCR, and its percentile, are described in much more detail in Appendix A. We currently recommend that the 25th percentile D/C Ratio be used to represent the risk for each demand variable, across the many feasible postures for a given task.

Body Mass Magnitude or Percentile: One of three percentiles can be selected (5^{th}, 50^{th} and 95^{th}) for the body mass of the digital human model, and these are associated with the Sex selected previously. Alternatively, the actual mass can be input, but must be within the range from the 1^{st} to 99^{th} female or male body mass. The ranges for Females are 45 to 138 kg (98 to 303 lbs), and for Males are 53 to 155 kg (or 117 to 341 lbs).

Stature Percentile: One of three percentiles can be selected (5^{th}, 50^{th} and 95^{th}) to determine stature of the digital human model used in the analyses, and these are associated with the Sex selected earlier. More details are provided in the Outputs section.

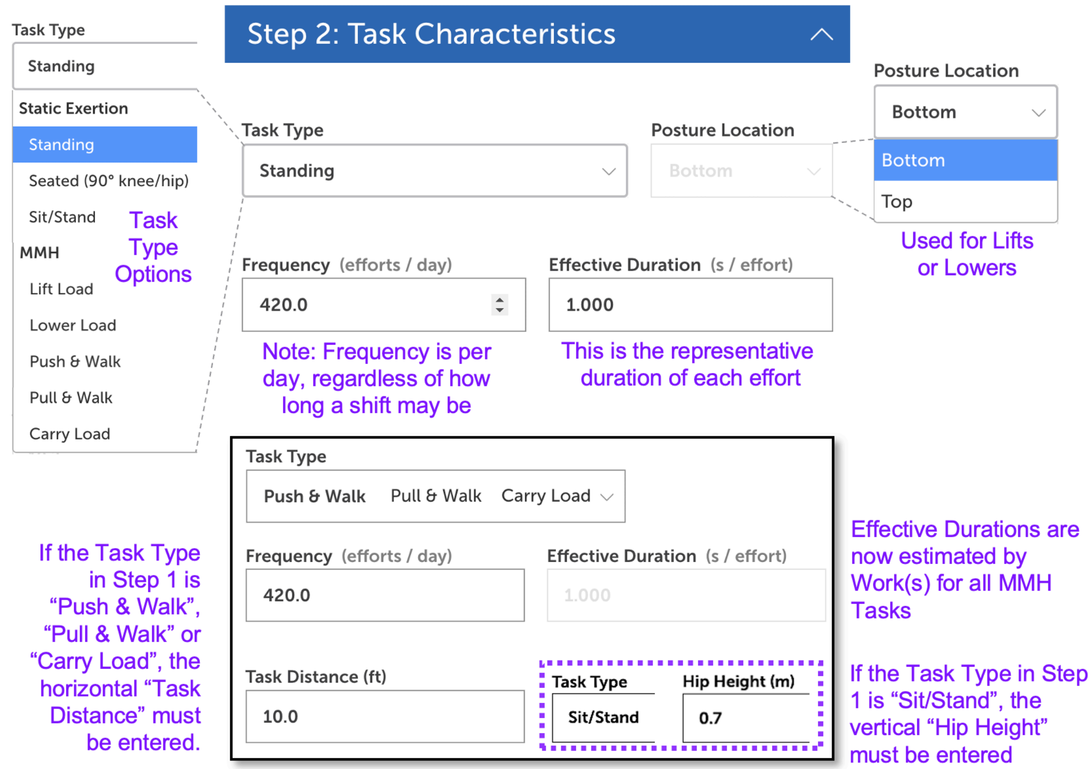
Percent Capable: Within a population, there are a wide range of capacities for any type of demand. Further, for any specific demand, there will be a percentage of the population that is capable of meeting that demand, such that the remainder of the population would be incapable of meeting that demand. Most ergonomics analyses use the 75 percent capable value as the threshold for demand, meaning the acceptable demand is within the capabilities of 75% of the population but exceeds the capabilities of the “weakest” 25 percent of the population. The user can input any whole number from 5 to 95 percent.

Next Button: At the end of each step, clicking the “Next” button will engage the next step. You can also click on the down or up arrow on the right of the blue bar to open or close the next step, respectively.

Step 2: Task Characteristics

In this step, the user inputs variables like task typed, frequency, effort duration, and task distance (where applicable).

Task Type: The tasks in Work(s) are grouped as “Static Exertions”, including standing, seated or sit/stand efforts, or “Manual Materials Handling (“MMH”), including lift, lower, push, pull & carry tasks. MMH tasks will use the LM-MMH Equations, so must conform to their constraints (i.e. mostly in the sagittal plane, symmetrical bilateral hand forces and hand heights etc.). To assess MMH tasks with large trunk lateral bends and/or axial twists, and/or with asymmetrical hand forces, the Static Exertion Standing module should be used.



Posture Location: Currently, Work(s) will only perform a biomechanical analysis on the postures associated with one hand location. Now, for “Lift Load” and “Lower Load” task, the user must choose the Bottom or Top hand height for the posture analysis. This should be the hand height assumed to have the highest risk. If you are unsure, run Work(s) at both posture locations, and use highest Overall DCR. If both heights are run, the user will be able to use different hand orientations and/or barriers at each height.

Frequency: Work(s) uses the frequency of efforts per day, instead of frequency per minute, as it is easier to determine and does not depend on when the task efforts are performed. We use assessment tools that, where applicable, base their capacity limits on an 8-hour workday, assuming a total of 1 hour of breaks such that there are 7 hours (420 minutes) of work. Thus, work done for <7 hours will tend to have lower frequencies and higher limits, and work done for >7 hours will tend to have higher frequencies and lower limits.

Effective Duration: The fatigue caused by an effort will depend on the full-time history of the force or torque and can be approximated with the mechanical impulse, which is the area under the force-time curve. Since impulse = (force)(time), then time = (impulse)/(force). We define the effort by the peak force, so the “effective duration” is the impulse divided by the peak force. It is not sufficient to estimate the effective duration as the total duration the hand is in contact with the load. For manual materials handling tasks, the effective durations are now estimated for the user, based travel distance and data from the scientific literature and using either the horizontal or vertical distance travelled. More details about effective duration are provided in Appendix B.

Task Distance/Hip Height: For manual materials handling tasks where the worker is pushing, pulling, or carrying a load while walking, there is an additional input of average horizontal distance travelled each time the load is pushed, pulled or carried (in meters for metric, or inches for imperial). Similarly, when the task is "Sit/Stand", the worker's hip height must be entered.

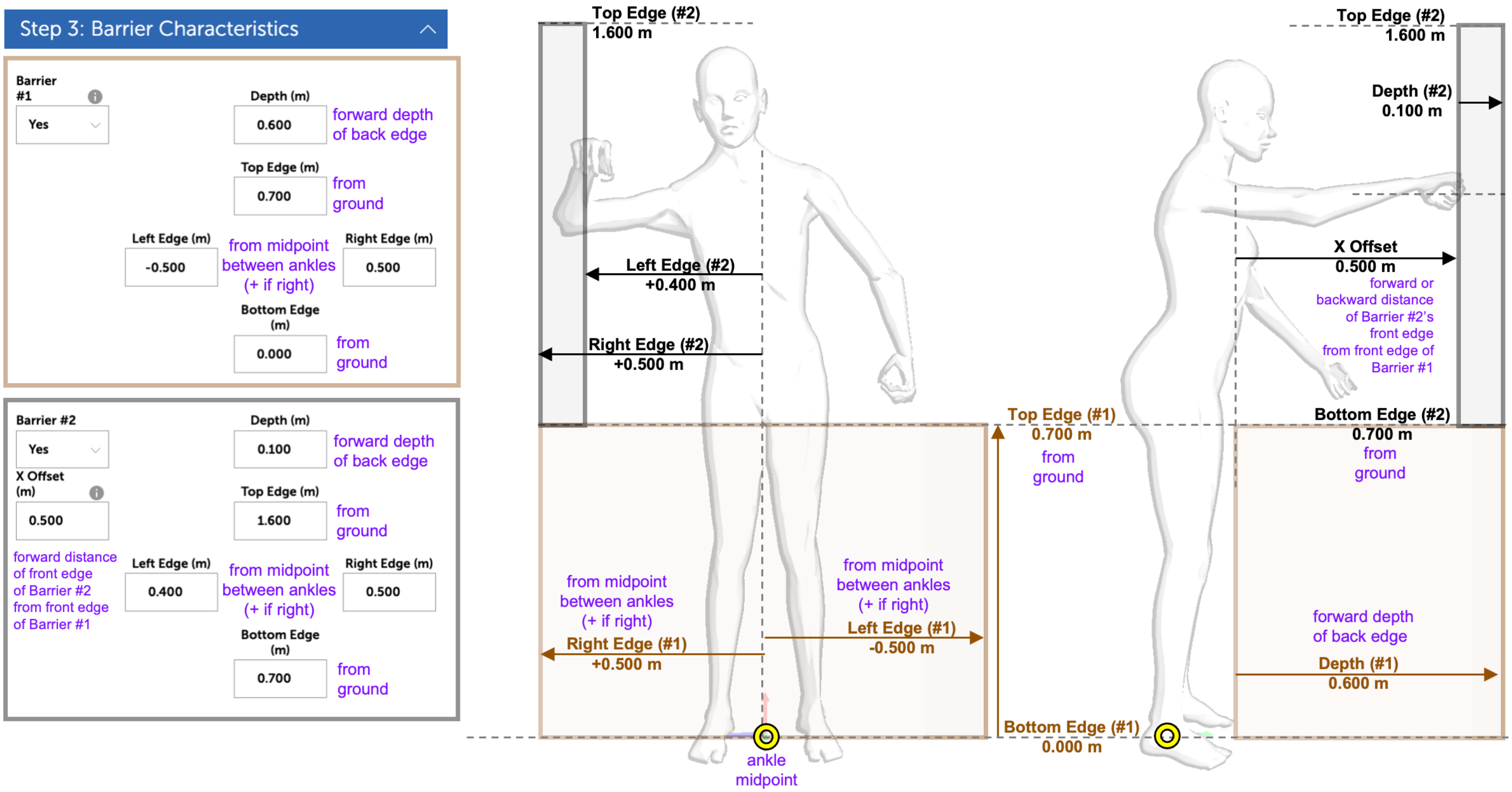
Step 3: Barrier Characteristics

In this step, the user will define the dimensions of one or two rectangular physical barriers. All dimensions are in meters or inches.

Depth: The anterior length of the horizontal surfaces
Top Edge: Height of the vertical surfaces' top edge
Bottom Edge: Height of the vertical surfaces' bottom edge
Left Edge: Distance of the left side edge from the middle of the ankles. Negative is to the left and positive is to the right.
Right Edge: Distance of the right-side edge from the middle of the ankles. Negative is to the left and positive is to the right.
X Offset: For only Barrier #2 (if applicable), X Offset is the forward displacement of Barrier #2's anterior vertical surface from Barrier #1's anterior vertical surface. **Note 1**: Barrier #2 cannot be posterior to Barrier #1.

In the example below, Barrier #1 sits on the floor, with a height of 0.7 m, the left edge is 0.5 m to the left of the middle of the ankles and the right edge is 0.5 m to the right of the middle of the ankles. Barrier #2's anterior vertical surface is 0.5 m forward of Barrier #1's, and has a bottom height of 0.7 m and a top height of 1.6 m. It is located to the right of the middle of the ankles. Note that the manikin is only shown here (in a single posture) to provide a frame of reference. For each posture, we assume the manikin gets as close as possible to Barrier #1. When a barrier is present and Body Bracing (see below) is activated, v1.10 will add postures with the manikin standing further back and leaning forward on the barrier. We assume that the end of the toe is 0.20 m (7.9") and 0.25 m (9.8") anterior of the ankles for females and males, respectively (Potvin et al., 2021).

Note 2: Barriers do not necessarily need to replicate the exact complex task environment. Instead, they should be of a shape and location to obstruct postures that would not be possible in that environment. In our experience, two well placed barriers are usually sufficient to facilitate realistic postures in most environments.



Step 4: Hand Contact Locations

In this step, the user defines the locations of the contact points of the hands, which depend on the hand grips/pinches that will be defined in Step 6. All units are in meters (metric) or inches (imperial).

Turn Off an Arm: Either the left or right arm can be turned off (but not both). If turned off, all relevant inputs for that arm are greyed out and Work(s) assumes that arm is placed at the side of the body.

Coordinates:
X: The X-axis is defined with Forward being positive and Backward being negative (in meters or inches). With no barriers, the forward locations of the hand contact points are taken with respect to the middle of the ankles. With at least one barrier, the forward locations are taken with respect to the anterior vertical surface of Barrier #1.

Note 1: the ends of the toes are assumed to be 0.20 m (7.87”) and 0.25 m (9.84”) anterior to the ankle for females and males, respectively. So, if you want the reach to be the same with a barrier, as it would be without one, the X (anterior distance) will need to be reduced by 0.20 m (or 7.87”) for females, and 0.25 m (or 9.84”) for males.

Y: The Y-axis is defined with Up being positive with respect to the ground
Z: The Z-axis is defined as Right being positive and Left being negative.

Step 4: Hand Contact Locations

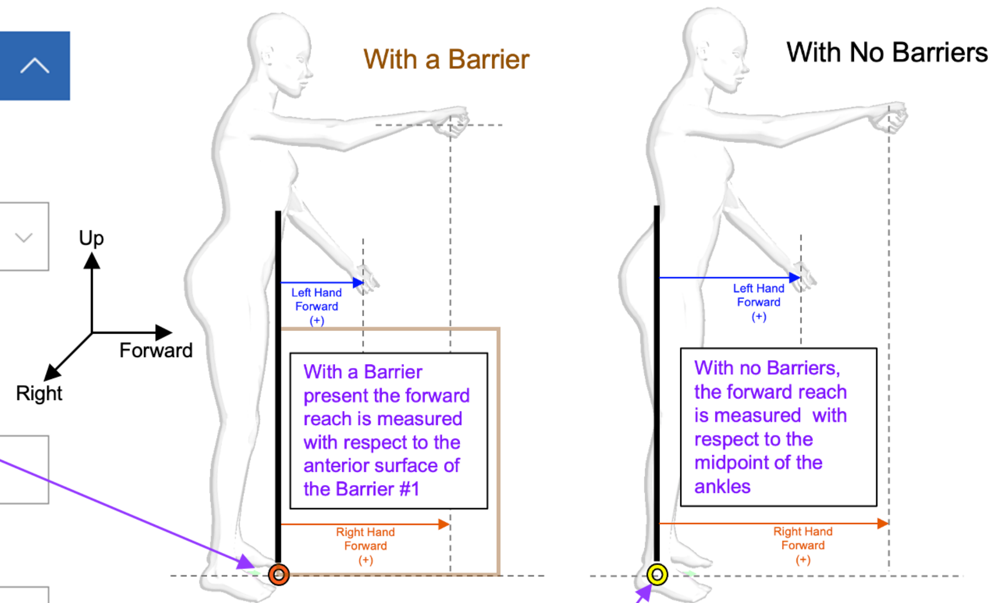
Turning an arm off greys out the inputs and places its hand at the side

Turn Left Arm Off	Turn Right Arm Off
No	No

With a Barrier

	Left	Right
X (m): +Forward / -Backward wrt Barrier #1 Front Edge	0.150	0.350
Y (m): +Up wrt the Ground	0.800	1.200
Z (m): +Right / -Left wrt the Middle of the Ankles	-0.250	0.300

The forward distance from the ankle to the toe is assumed to be 0.20 m (Females) & 0.25 m (Males)



With no Barriers

	Left	Right
X (m): +Forward wrt Middle of Ankles	0.350	0.550
Y (m): +Up wrt the Ground	0.800	1.200
Z (m): +Right / -Left wrt the Middle of the Ankles	-0.250	0.300

Step 4: Hand Contact Locations (continued)

Note 2: For Lift and Lower tasks only, the user must define the hand contact locations at the “Bottom” height (ie. the lower of the two heights, so the origin of lift or destination of lower) and the “Top” height (i.e. the higher of the two heights, so the destination of lift or origin of lower) of the movement. For Lifts and Lowers, the direction of the forces on the left and right hand (Step 5) are always assumed to be Up.

Note 3: For push, pull and carry tasks, only one hand height (Y) can be input. Also, for push and pull tasks, it is difficult to estimate what reaches would be used, so we’ve estimated the reach distances (X) based on data from Chaffin, Andres & Garg (1983). To use these modules, the tasks should occur mainly in the sagittal plane, with both arms applying the same force (so arms cannot be turned off in the MMH modules). In addition, for push, pull and carry tasks, the hand heights are limited to the ranges studied in the Liberty Mutual psychophysical studies.

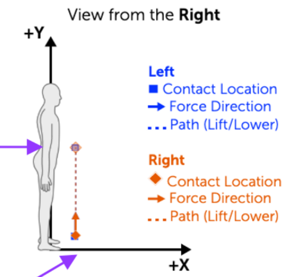
Step 4: Hand Contact Locations

Lift & Lower Tasks are assumed to be 2-handed

Turn Left Arm Off	Turn Right Arm Off
No	No

	Left	Right
Top		
X (m): +Forward wrt Middle of Ankles	0.250	0.250
Y (m): +Up wrt the Ground	1.000	1.000
Z (m): +Right / -Left wrt the Middle of the Ankles	-0.200	0.200
Bottom		
X (m): +Forward wrt Middle of Ankles	0.250	0.250
Y (m): +Up wrt the Ground	0.150	0.150
Z (m): +Right / -Left wrt the Middle of the Ankles	-0.200	0.200

Hand Contact Locations & Force Directions



This graphic provides a visual verification of the input of the locations of the left and right hands

This is an example from a Lift or Lower task where the hand locations from the Top and Bottom of the movement are input

For Push & Pull tasks, the forward reach is estimated, and for Push, Pull & Carry both hands are assumed to be at the same height

	Left	Right
X (in): +Forward wrt Middle of Ankles	0.000	0.000
Y (in): +Up wrt the Ground	0.000	0.000
Z (in): +Right / -Left wrt the Middle of the Ankles	0.000	0.000

Step 5: Force Parameters

In this step, the user defines the hand effort directions and magnitudes. Currently, Work(s) only supports the input of linear forces (not moments/torques).

Hand Effort Directions: Force directions represent the direction that the force is applied by the hand, and can be entered as the absolute or relative magnitudes in each direction. As with hand contact locations, the X-axis is Forward (positive) and Backward (negative), the Y-axis is Up (positive) and Down (negative) and the Z-axis is Right (positive) and Left (negative). If an arm is turned off, the inputs are greyed out. Any combination of Forward/Back, Up/Down and Right/Left direction can be entered, though users will often enter simple combinations of -1.000 or 1.000 for 1, 2 or 3 axes. In the example inputs below, the force is equal parts Forward and Up for the left hand (blue arrow) and only Left for the right hand (orange arrow). Additional examples are provided in the table below on the right for the six primary directions and then some combinations of directions.

Force directions are assumed to be Up for Lift, Lower and Carry tasks, Forward for Push tasks and Backward for Pull tasks.

Note: For previous users of Jack, Process Simulate, 3DSSPP and/or Santos, note that those packages require input of the direction of the force acting ON the hand(s) (ie. reaction forces), but Work(s) requires input of the direction of the forces applied BY the hand(s).

Example	X Fwd/Back	Y Up/Dwn	Z Rt/Lft	
Forward	+1.000	0	0	
Backward	-1.000	0	0	
Up	0	+1.000	0	
Down	0	-1.000	0	
Right	0	0	+1.000	
Left	0	0	-1.000	
Forward & Down (equally)	+1.000	-1.000	0	
More Forward, some Up	+3.000	-1.000	0	
Forward , Up and Left (Equally)	+1.000	+1.000	-1.000	
	+0.577	+0.577	-0.577	Unit Vector
	+27.5	+27.5	+27.5	Actual Force

For the last example, equal forces in the Forward, Up and Right directions can be input as (1) the unit vector of +0.577 in each direction, or (2) as +1.000 in each direction, or (3) the actual force of +27.5 N in in each direction.

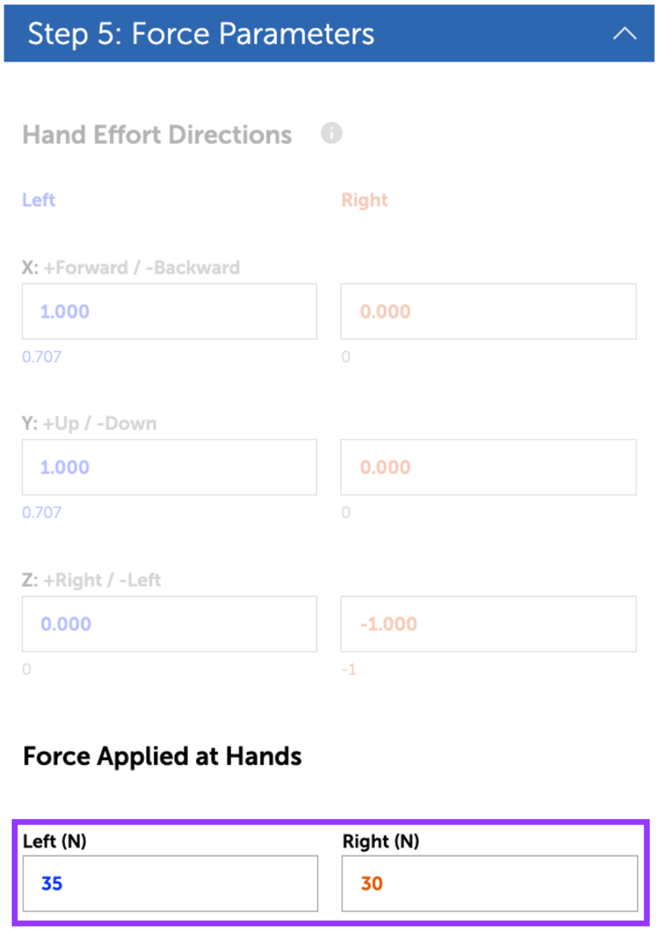
Regardless of how the force combinations are input, the unit vectors are determined and used in any further calculations (and shown below the boxes).

Step 5: Force Parameters (continued)

Force Applied at Hands: The user must enter the force magnitudes in newtons (for metric) or pounds (for imperial).

For all manual materials handling modules, symmetry is assumed for the forces on the right and left hands, so only one total force is entered.

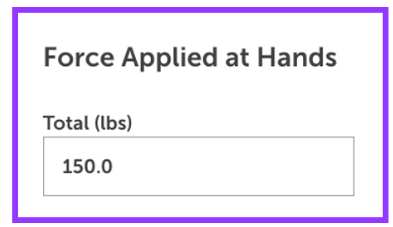
If the “Push & Walk” or “Pull & Walk” task is selected, the user must enter the total Initial force and total Sustained force.



This is where the magnitude of the forces are input (Newtons for Metric units, Pounds of force for Imperial units)

Total Initial & Total Sustained Forces are required for “Push & Walk” & “Pull & Walk” Tasks

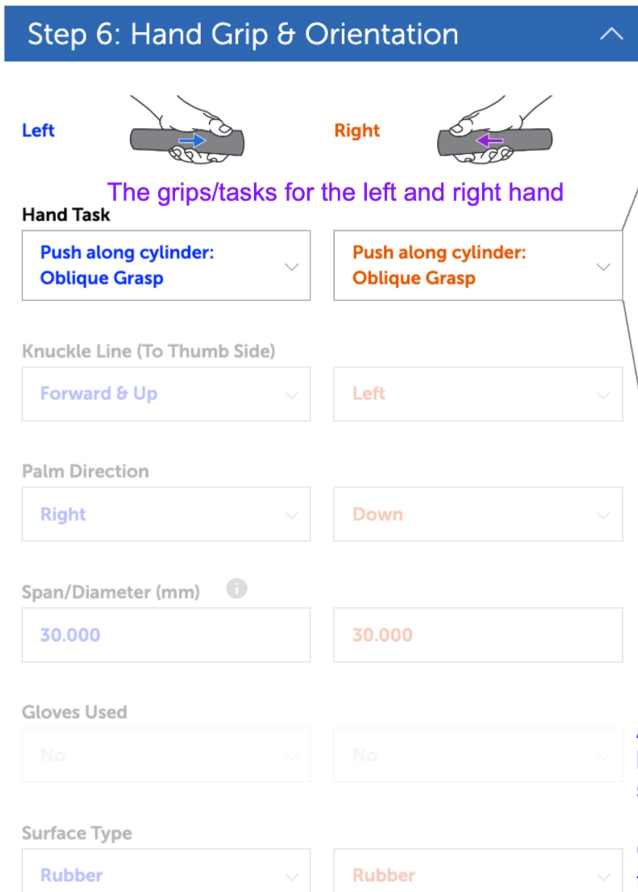
Total Forces are required for “Lift Load”, “Lower Load” and “Carry Load” Tasks



Step 6: Hand Grip & Orientation

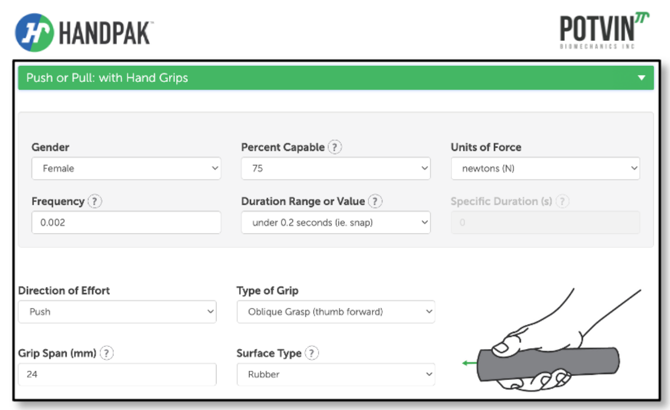
In this step, the user defines the hand tasks, orientation of the hands (via the direction of the knuckles and the palms) and, where relevant, the span/diameter of the object, whether gloves are used and the surface type. Step 6 is where you enter the inputs for the HandPak™ assessment tool (Potvin Biomechanics Inc., Tecumseh, Ontario, Canada) embedded within Work(s) for the fingers, hands, wrists, and forearms. More details about HandPak™ are provided in the Outputs section.

Hand Tasks: The first step is to define the hand posture and grip used each hand. If one hand is turned off, it's column will be greyed out. The 23 interfaces are the same as in HandPak and include power grips, pinches, and finger and thumb interfaces to push or pull on an object. Graphics of the grip/pinch are provided as feedback above the input box after the hand task is selected. Each grip and pinch are shown below in the bottom right. Note: HandPak is not invoked for the Flat Hand posture or the Power Grip posture (unless the force is acting directly parallel to the palm into the wrist).



Grip/pinch options

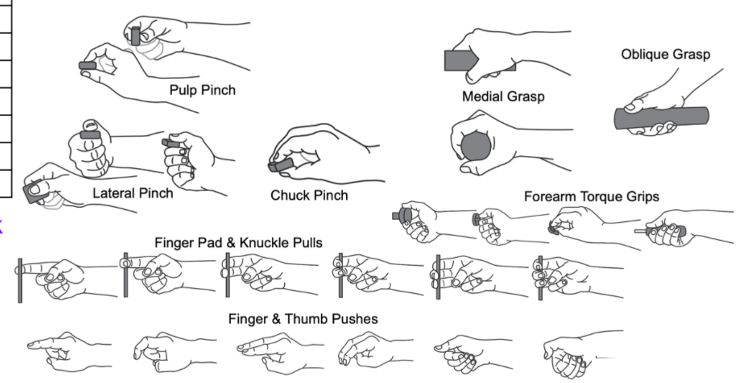
Generic (No HandPak)		Power Grip (Medial Grasp)
		Flat Hand
Push	Pinch	Lateral Pinch
		Pulp Pinch
		Chuck Pinch
	Finger(s)	Tip of Index Finger
		Pad of Index Finger
		Tips of Two Fingers
		Pad of Two Fingers
	Thumb	Tip of Thumb
		Pad of Thumb
	Cylinder	Along cylinder/hose: Oblique Grasp
		Along cylinder/hose: Medial Grasp
Pull	Pinch	Lateral Pinch
		Pulp Pinch
		Chuck Pinch
	Finger	1 Finger - Tip
		1 Finger - Last Knuckle
		2 Fingers - Tips
		2 Fingers - Last Knuckles
		3 Fingers - Tip
		3 Fingers - Last Knuckle
	Cylnder	Along cylinder/hose: Oblique Grasp
		Along cylinder/hose: Medial Grasp



Integrating HandPak™

All grips associated with the HandPak linear force tasks are available for selection.

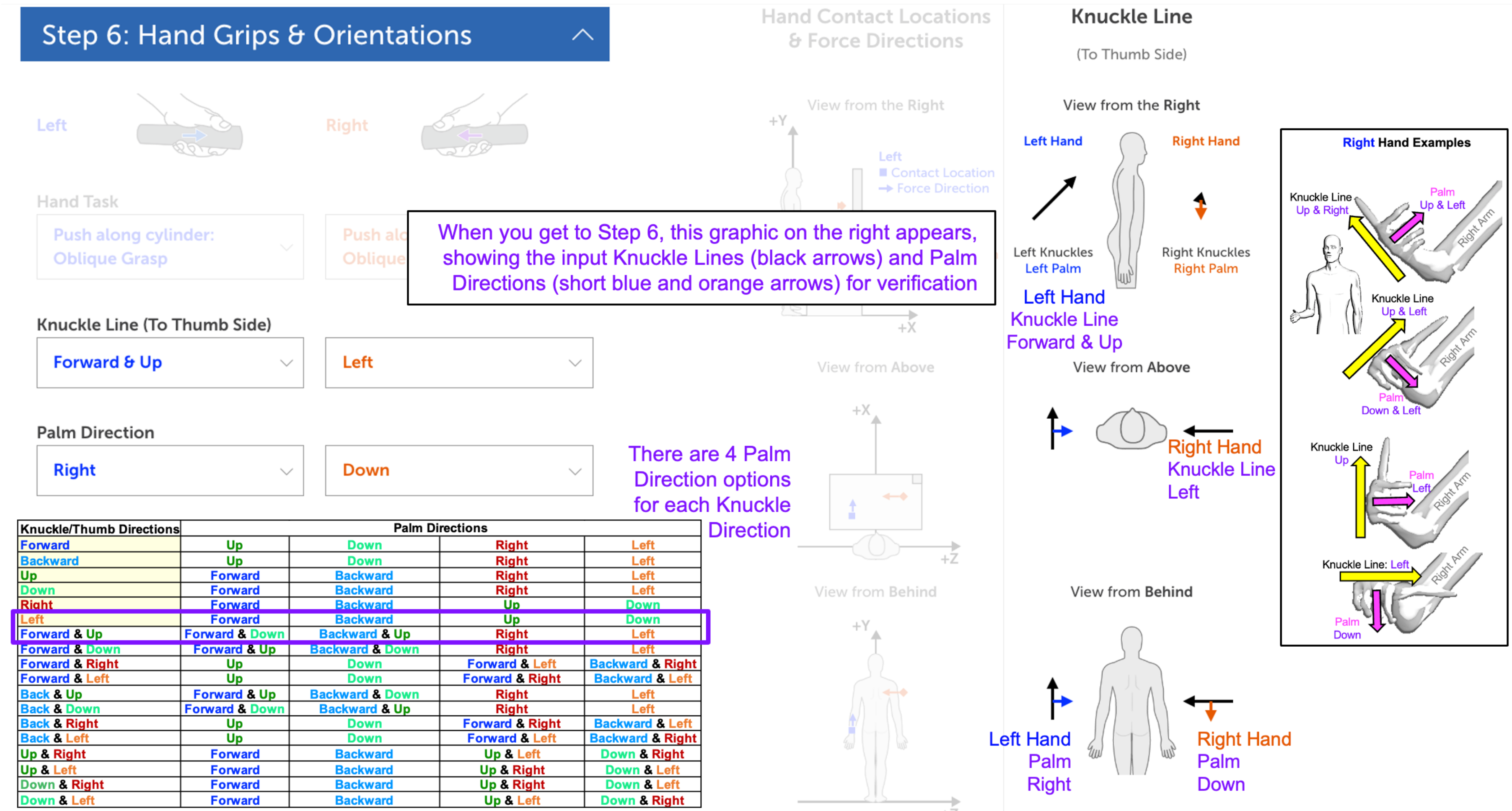
Currently, wrist and forearm torque tasks must be assessed in HandPak



Step 6: Hand Grip & Orientation (continued)

Knuckle Line: The knuckle line direction is defined by the line through the knuckles towards the thumb side. This can be in the six primary directions (e.g. Forward) and the 12 directions between two of the orthogonal directions (e.g. Forward & Up, Right & Down, etc.). The table in the bottom left shows the 18 directions that can be selected. On the input interface, the three views under "Knuckle Line" show the selected knuckle direction as a dark black arrow, for visual verification.

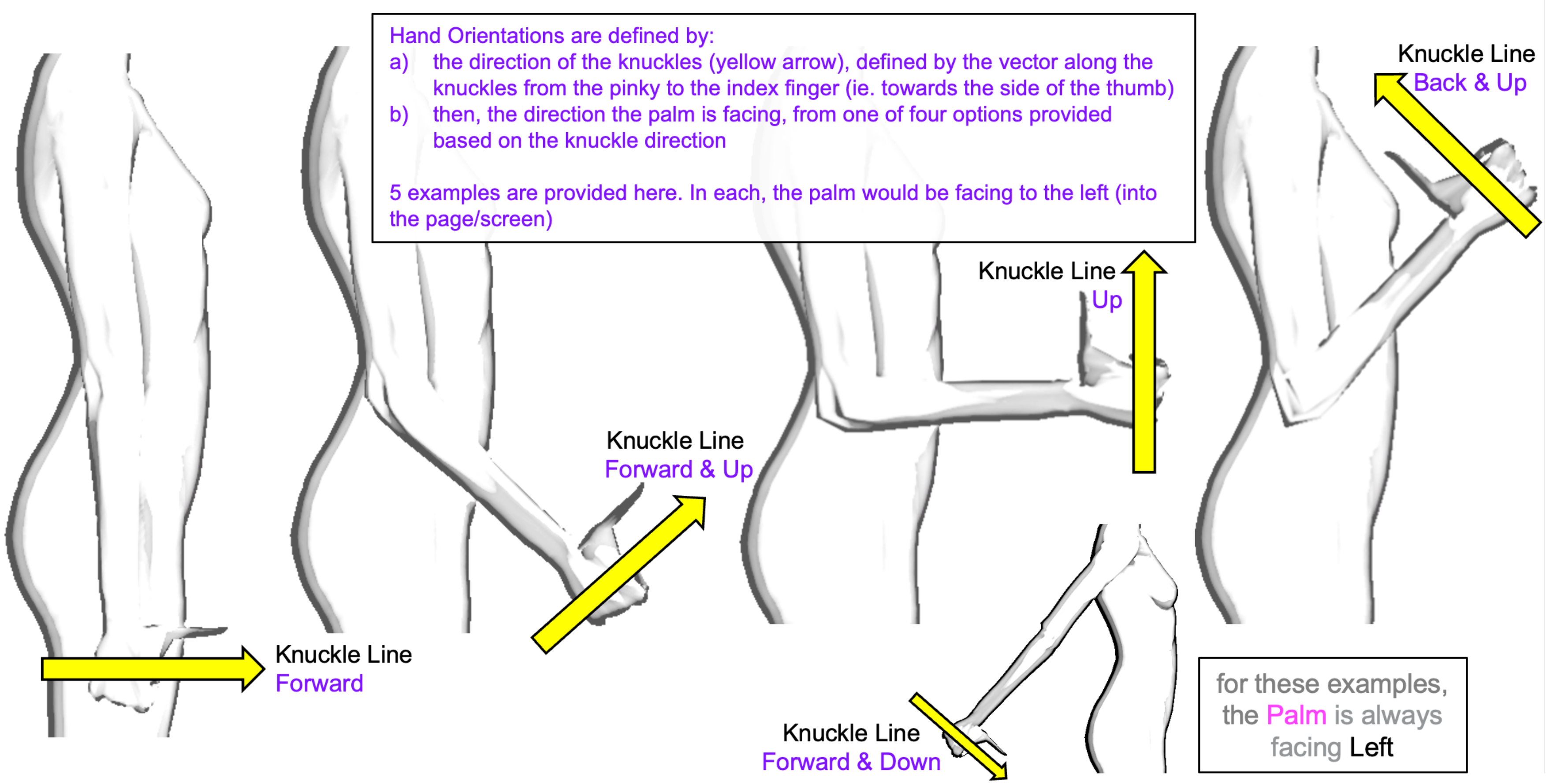
Palm Direction: Once the knuckle line direction is selected, the user will be provided with four options for the Palm Direction. In the example below, the right knuckle line was input as "Forward & Up", such that the four options for palm direction were "Forward & Down", "Backward & Up", "Right" and "Left", of which "Right" was selected. Four examples of combinations of knuckle line and palm direction are shown below in the graphics on the right. More examples are provided on the next page.



Knuckle/Thumb Directions	Palm Directions			
Forward	Up	Down	Right	Left
Backward	Up	Down	Right	Left
Up	Forward	Backward	Right	Left
Down	Forward	Backward	Right	Left
Right	Forward	Backward	Up	Down
Left	Forward	Backward	Up	Down
Forward & Up	Forward & Down	Backward & Up	Right	Left
Forward & Down	Forward & Up	Backward & Down	Right	Left
Forward & Right	Up	Down	Forward & Left	Backward & Right
Forward & Left	Up	Down	Forward & Right	Backward & Left
Back & Up	Forward & Up	Backward & Down	Right	Left
Back & Down	Forward & Down	Backward & Up	Right	Left
Back & Right	Up	Down	Forward & Right	Backward & Left
Back & Left	Up	Down	Forward & Left	Backward & Right
Up & Right	Forward	Backward	Up & Left	Down & Right
Up & Left	Forward	Backward	Up & Right	Down & Left
Down & Right	Forward	Backward	Up & Right	Down & Left
Down & Left	Forward	Backward	Up & Left	Down & Right

Step 6: Hand Grip & Orientation (continued)

Knuckle Line & Palm Direction (continued)

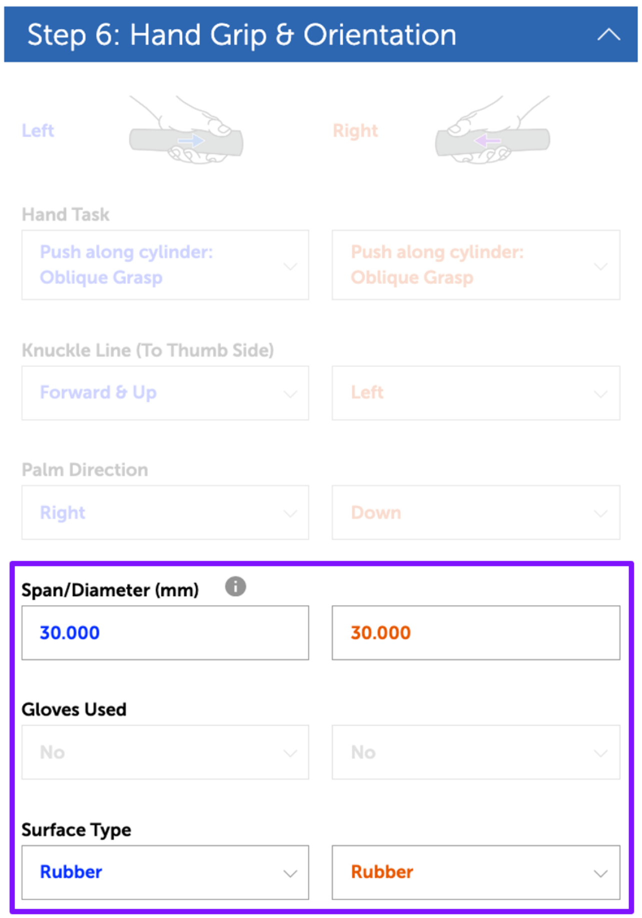


Step 6: Hand Grip & Orientation (continued)

Span/Diameter: For some hand grips or pinches, the user will be asked to enter the span or diameter of the object being gripped or pinched. This represents the diameter of a power grip or the distance between the fingers for pinches (in mm for metric or inches for imperial).

Gloves Used?: For tasks involving pulling with the fingers, the user will indicate if gloves are worn.

Surface Type: For tasks involving pushing or pulling with a medial grip or oblique grasp, the user will input whether the surface is rubber (e.g. pushing along a hose) or plastic (e.g. pulling along a wire harness).



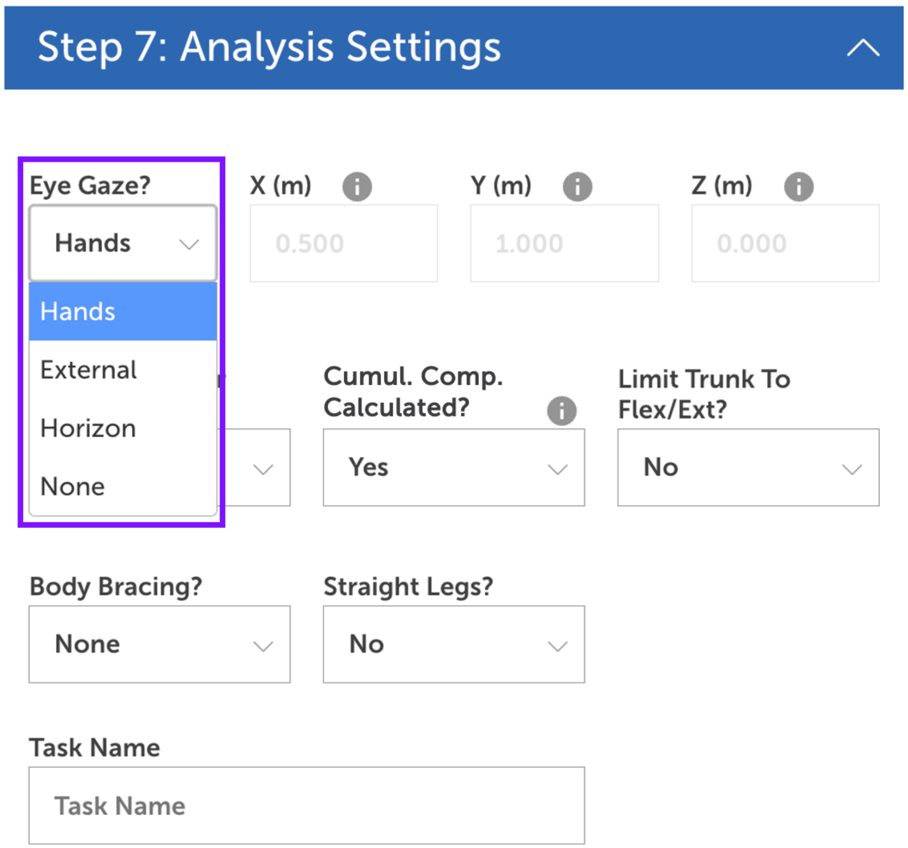
Some hand grips/pinches require the input of some combination of the following:

- Span/Diameter (mm or inches)
- Are Gloves used (Yes or No)
- Type of Surface (Rubber or Plastic)

Step 7: Analysis Settings

In this step, the user indicates some additional analysis settings including the direction of the eye gaze, whether the above-shoulder correction will be used, if the body is bracing against a barrier, if the trunk posture will be limited to flexion/extension rotations, if the legs will be straight, and if the new cumulative compression variable will be used in the DCR scores (details about this below).

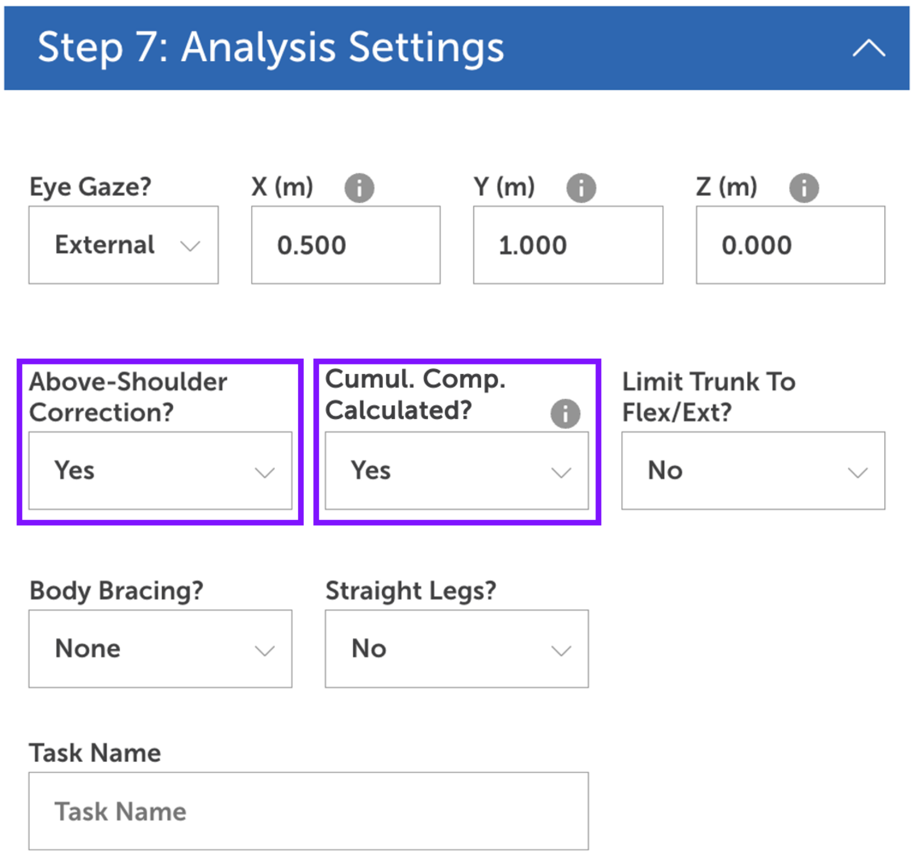
Eye Gaze?: The user can indicate if there is eye gaze directed towards (1) the hands, (2) an external target XYZ location, (3) the horizon, or (3) none. If the "Hands" are selected, the focal point will be between the hand contact locations, weighted to the force on each hand. If an "External" focal point is selected the user must indicate the XYZ coordinates, using the same reference system as used for the hand contact locations. If "Horizon" is selected, the head will remain upright, and if "None" is selected, the neck remains in a neutral posture with respect to the trunk. As, such, this selection will generally only affect the neck posture and DCR.



Step 7: Analysis Settings (continued)

Above-Shoulder Correction?: Select “Yes” to turn on the above-shoulder correction using the method of Rempel & Potvin (2022), which calculates the manual arm strength from the Arm Force Field method of La Delfa & Potvin (2017), then estimates the glenohumeral angle based on the humerothoracic angle, and corrects the arm strength down as the glenohumeral angle increases from 60 to 90 deg. More detail is provided in the Outputs section. Note that the published Rempel & Potvin (2022) outputs for the anterior and superior effort directions is now the ACGIH TLV for Above Shoulder Work (ACGIH, 2024).

Cumulative Compression Calculated?: We’ve recently developed a method to calculate the lumbar compression force cumulative damage associated with repetitive peak lumbar compression forces. These can be used to assess isolated tasks or to combine the risk from multiple subtasks. More detail is provided in the Outputs section. If you don’t wish to incorporate this new measure into the DCR values calculated in the Work(s) output, then select “No” for this option.



Step 7: Analysis Settings (continued)

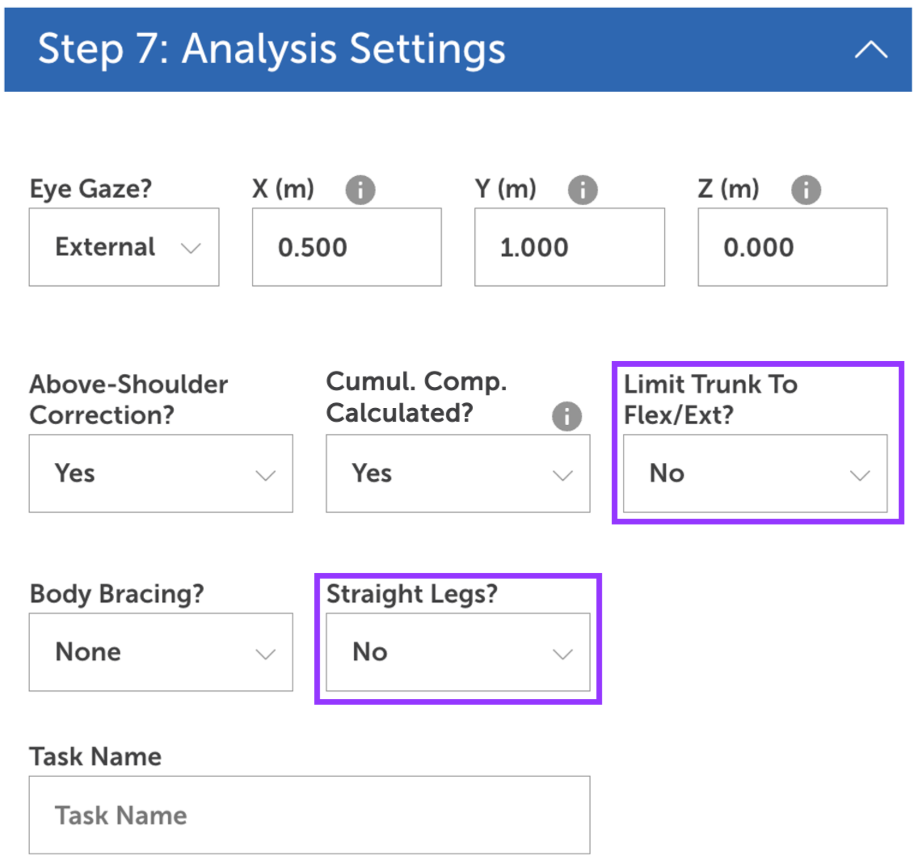
Limit Trunk to Flexion/Extension?: It is not likely that there would be noticeable trunk axial twisting or lateral bending during tasks that have the following two characteristics;

1) symmetrical hand locations, on either side of the sagittal plane (ie. midline of the body.)
2) forces in the same direction with the same magnitudes.

In such cases, those off-axis rotations can be turned off so only trunk flexion/extension postures are evaluated. This is only suggested in cases where the hand locations and forces are mirrored on the sagittal plane. This will have two benefits:

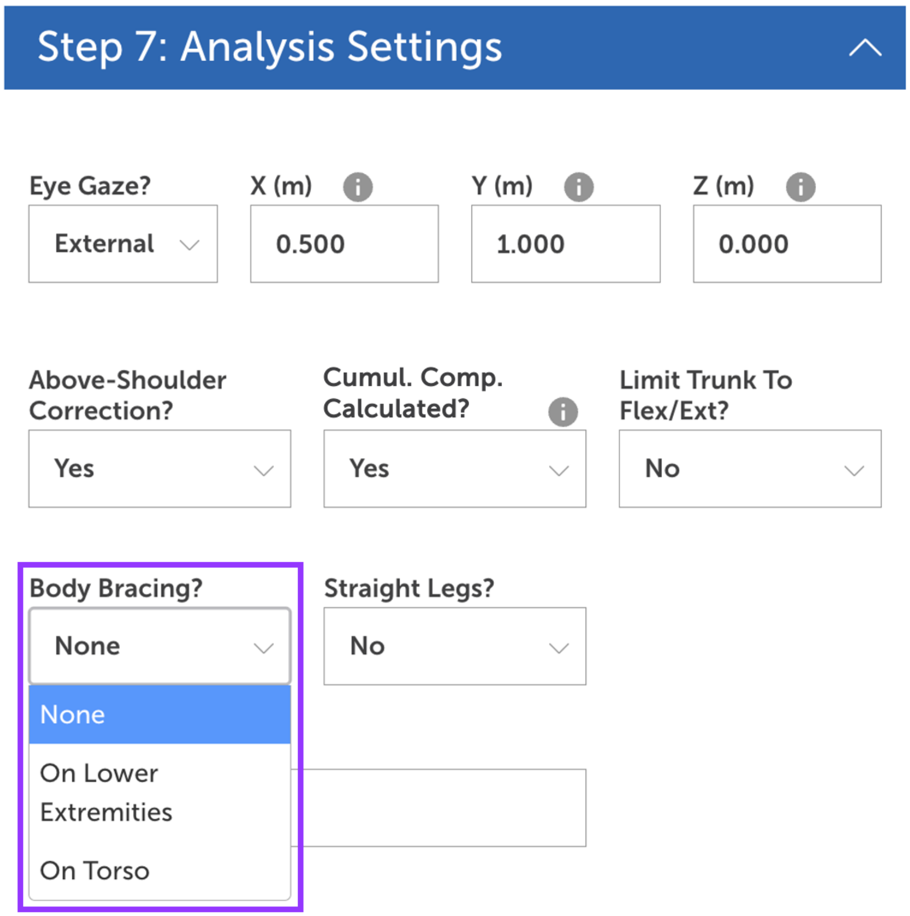
1) reduce the processing time
2) eliminate feasible, but unlikely, asymmetrical postures with high risk from the DCR distributions.

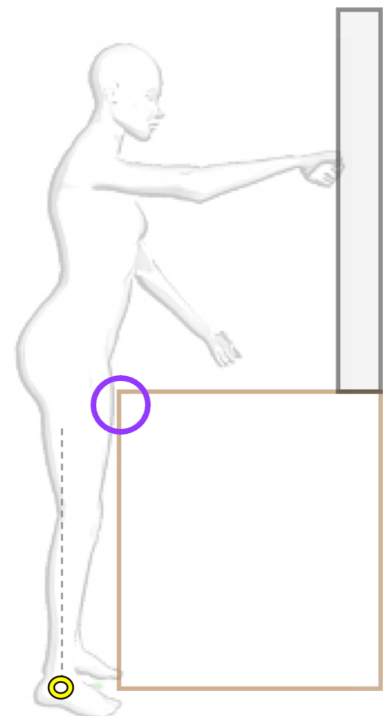
Straight Legs?: The user can set the legs to be straight for tasks where they don't expect knee flexion or anterior/posterior spreading of the feet (eg. work done above the shoulder). As with limiting trunk rotations to flexion/extension, this will speed up the processing and eliminate postures deemed to be highly unlikely.



Step 7: Analysis Settings (continued)

Allow Body Bracing?: "Bracing" occurs when the lower extremity or torso can come in contact with a barrier. Without body bracing, postures can be eliminated if the center of pressure moves forward of the base of the support. With body bracing, this constraint is removed as it is assumed that the barrier is providing sufficient support and stability. Bracing can be on the lower extremities, or below the L5/S1 joint (shown below) or on the torso, or above the L5/S1 joint (in which case, the low back loading cannot be solved). Bracing should only be used when barriers are present.

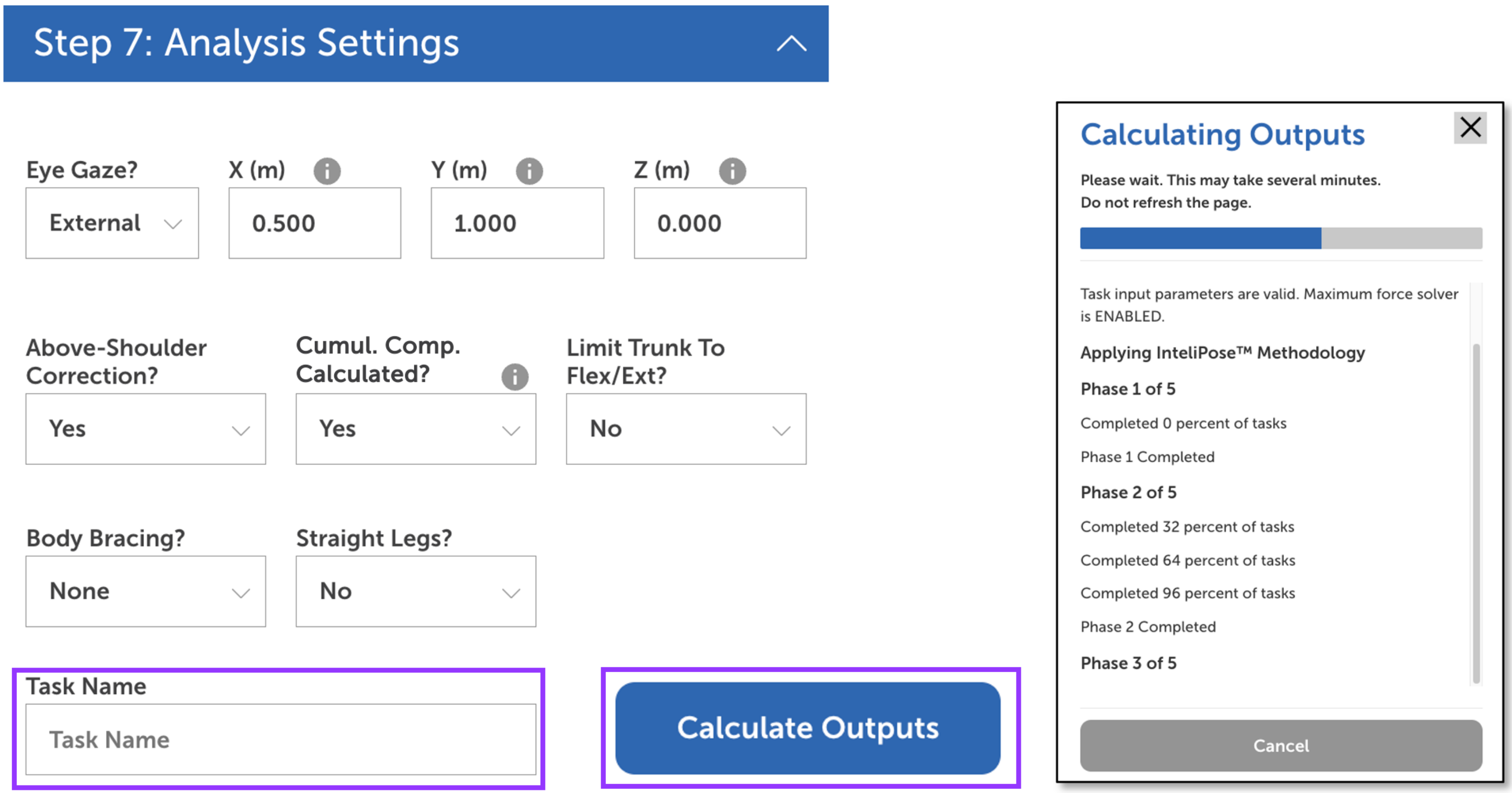




Step 7: Analysis Settings (continued)

Task Name: Enter the Task Name as a code identifying the analysis. This code will appear in the Summary sheet of the Excel Work(s) report (described later). If the code is left blank, the Excel report file will be named "Work(s) Report" and will still available for download at the Output interface (more details later).

Calculate Outputs: Once the inputs are finalized, click this button to calculate all outputs. After clicking, the window in the bottom right will appear indicating the progress during each step of the analysis. Once completed, the user can click on "View Outputs" and be taken to the Output page.



Feedback for Input Errors

The following examples illustrate the modes of feedback provided by Work(s) if input combinations are deemed to be unfeasible. The feedback is intended to identify potential input errors. In v1.1, if the hands are inside a barrier or beyond the reach envelope, the analysis will be stopped immediately, with feedback provided in the analysis window. For other input issues, Work(s) will provide input issue feedback on the "Output" screen and the user will have the option to save the Report file for future reference and troubleshooting.

Unavoidable Barriers

Outputs

Input Issue: The hand locations cannot be achieved without a collision with the barrier(s), given their size and/or location. Graphics provide a frame of reference for what the issue might be.

Solution: Check the accuracy of the barrier dimensions and/or the hand contact locations. Is the person really positioned in such a way that their hands contact directly behind the barrier.

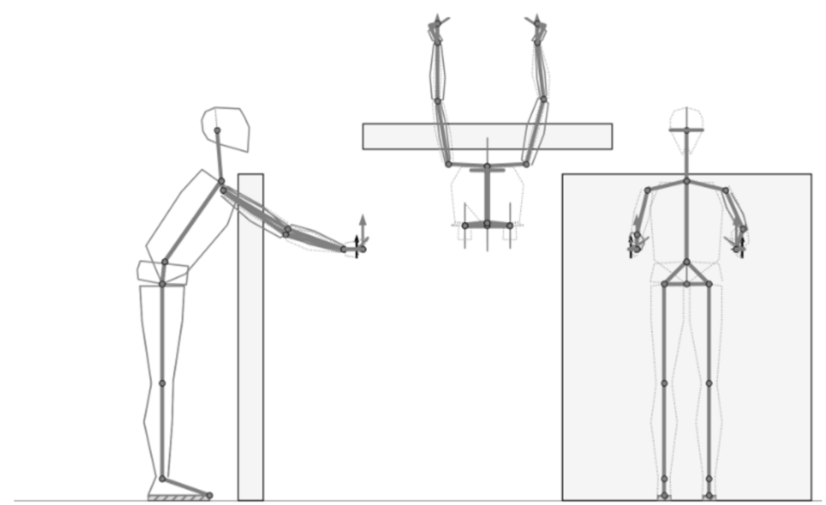
Issues

Issue: Barrier Collision. It is not possible to avoid the Barrier(s) as defined. The arms, or head, have passed into or collided with one of the Barriers, as indicated in the image.

Most likely cause(s): Hand Grips and Orientations, Hand Contact Locations, Barrier Dimensions, Anthropometry

Additional potential cause(s): Straight Legs (if set to Yes), Limit Trunk to Flex/Ext (if set to Yes)

Download and consult the Report File to help determine the source(s) of the issue.



Center of Pressure Outside the Base of Support

Outputs

Issues

Input Issue: In this example, the combination of the hand locations and the very high push force demands, place the center of pressure (COP) behind the feet, such that there is no feasible stable posture. Specifically, given the high push forces input, the COP is at least 0.597 m behind the foot.

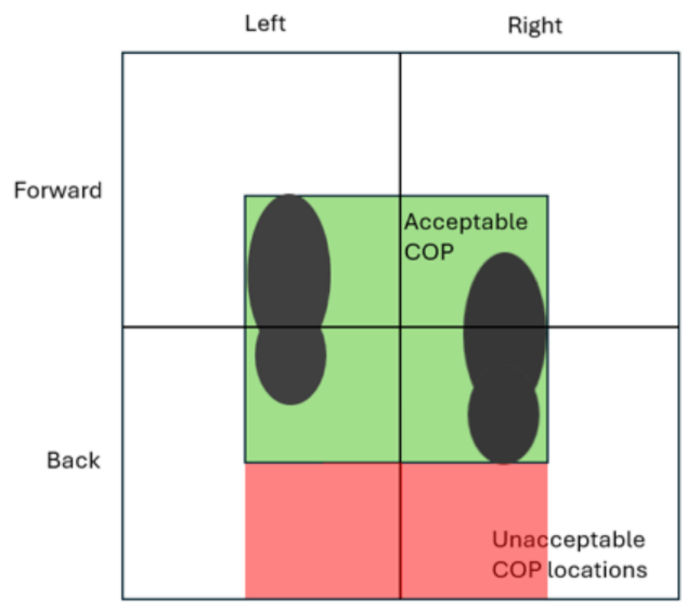
Solution: Check if the hands need to be that far forward for the push, and/or if the force magnitudes are really that high.

Issue: Center of Pressure. The estimated COP is behind the base of support by a minimum of 0.597 meters.The force on the hands may be rotating the body too far backward.

Most likely cause(s): Hand Contact Locations, Force Direction/Magnitude, Anthropometry

Additional potential cause(s): Straight Legs (if set to Yes)

Download and consult the Report File to help determine the source(s) of the issue.



No Feasible Wrist/Forearm Postures

Outputs

Input Issue: The left hand's orientation is not feasible for the hand contact location (ie. the thumb side is pointing up and the palm is facing forward. Specifically, 100% of the postures violate both the wrist "Flx/Ext" and "Uln/Rad" ranges of motion (ROM).

Solution: Check the left hand's orientation. Should the left thumb really be pointing up (light blue arrow) with the palm facing forward (pink arrow)?

Issues

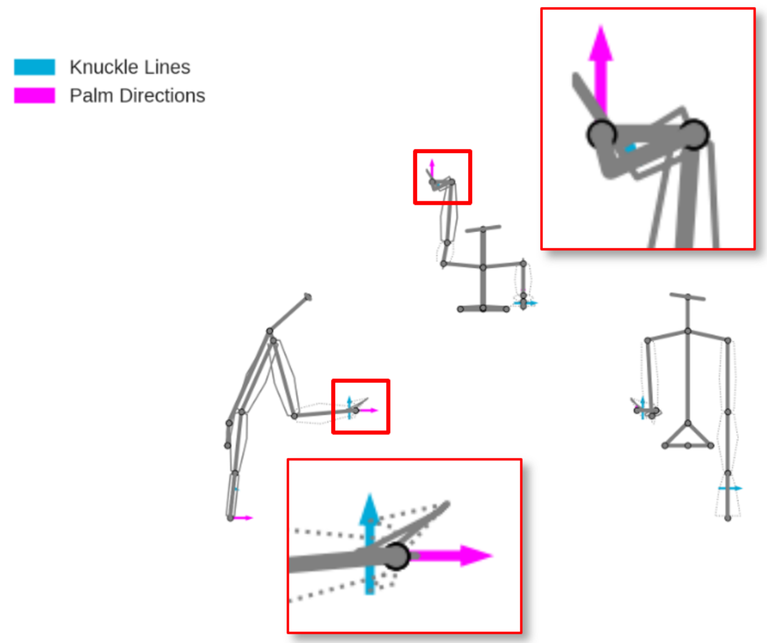
Issue: Range of Motion. At least one wrist and/or forearm ROM was violated for the right and/or left arm. The percentages of postures where the violation occurred about each wrist/forearm axis, are shown below:

Left Hand: Sup/Pro - 100 %, Uln/Rad - 100 %, Flx/Ext - 0 %
Right Hand: Feasible

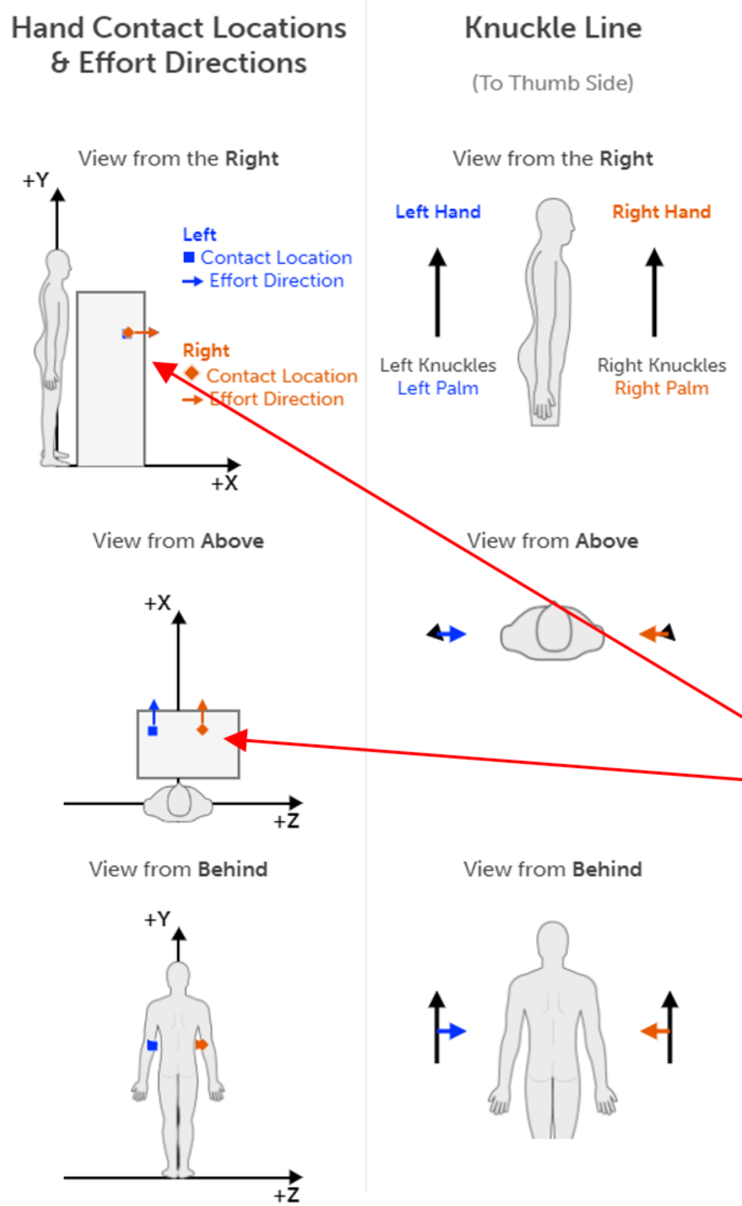
Most likely cause(s): Hand Grips and Orientations, Hand Contact Locations, Barrier Dimensions, Anthropometry

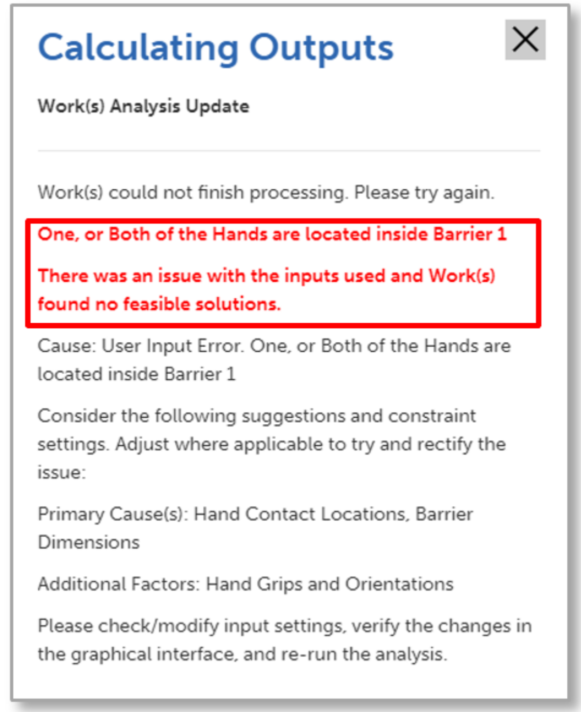
Additional potential cause(s): Straight Legs (if set to Yes), Limit Trunk to Flex/Ext (if set to Yes)

Download and consult the Report File to help determine the source(s) of the issue.



Hand(s) Inside a Barrier

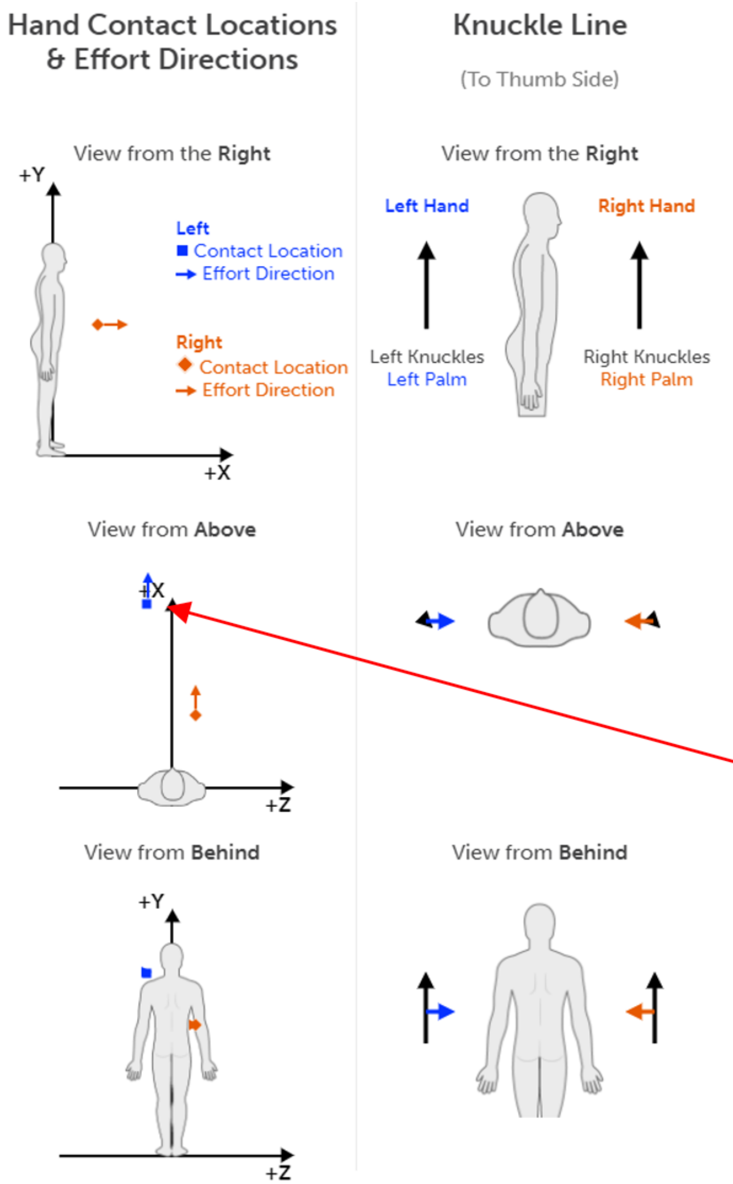


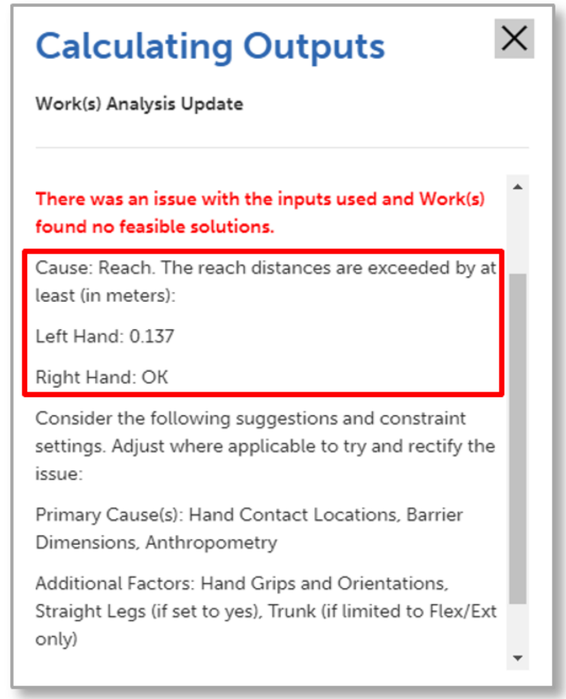


Input Issue: In this example, both hands are located within a barrier, which is not possible.

Solutions: Check the accuracy of the barrier dimensions & locations, and/or the hand contact locations.

Hand(s) Placed Beyond the Reach Envelope





Input Issue: In this example, the reach for the left hand is outside the feasible reach envelope. Specifically, the reach of the left hand is at least 0.137 m beyond it's reach envelope.

Solutions: check the accuracy of the left-hand contact locations. Is the left hand's forward distance really that high?

Outputs

Work(s) was designed to assess every posture and integrate every assessment for those performing ergonomics analyses of occupational tasks and jobs. To summarize, given hand locations, orientations, postures, interfaces and forces, Work(s) predicts the full range of feasible postures within the constraints of any physical barriers, all joint ranges of motion, and postural stability and balance. Then, a comprehensive ergonomics analysis is performed on a representative random sample of postures and the full distribution of risk scores, across postures, is fully integrated and summarized for the user. The following will briefly explain the process used by Work(s) to obtain its outputs.

Note: once every feasible posture is determined (sometimes >80,000 postures), a representative, randomly selected subset of those postures is selected for a full analysis with each assessment tool. This is necessary to substantially decrease the analysis time, but results in slightly different summary DCR values and graphics each time you run Work(s) with a particular set of inputs. However, if the Overall is close to 1.00, an analysis is performed on all postures to ensure that the correct decision is made.

Digital Human Models

Skeleton

Work(s) uses a digital human model (DHM) with 15 rigid-linked segments, including bilateral feet, lower legs, thighs, hands, forearms, and upper arms, as well as a pelvis, trunk (from the L5/S1 to C7/T1 joints) and head/neck segments. The assumptions and data used for whole-body, segment and joint anthropometries are explained below.

Body Mass & Stature

The NHANES database from 2015-2018 (Fryar et al, 2021) was used to calculate average body masses and statures across the age groups from 20 to 69. Those values are summarized in metric and imperial units in the table below.

		Female			Male		
		5th	50th	95th	5th	50th	95th
Body Mass	kg	50.4	73.5	120.7	63.0	88.1	132.0
	lbs	111.1	162.0	266.1	138.9	194.2	291.0
Stature	m	1.506	1.619	1.727	1.634	1.758	1.874
	in	59.3	63.7	68.0	64.3	69.2	73.8

Segment Anthropometry

Values for segment masses (as a ratio of body mass), lengths (as a ratio of stature), shapes and centers of mass (as a ratio of segment length) are based on a compilation of data from the literature (Grenier, 1991; Buchholtz et al., 1992; Tilley, 1993; DeLeva, 1996; Durkin & Dowling, 2003; Chaffin et al., 2006). Unique forearm and upper arm segment length ratios were used for the 5th, 50th and 95th females and males, based on data from Fromuth & Parkinson (2008)

Joint Range of Motion

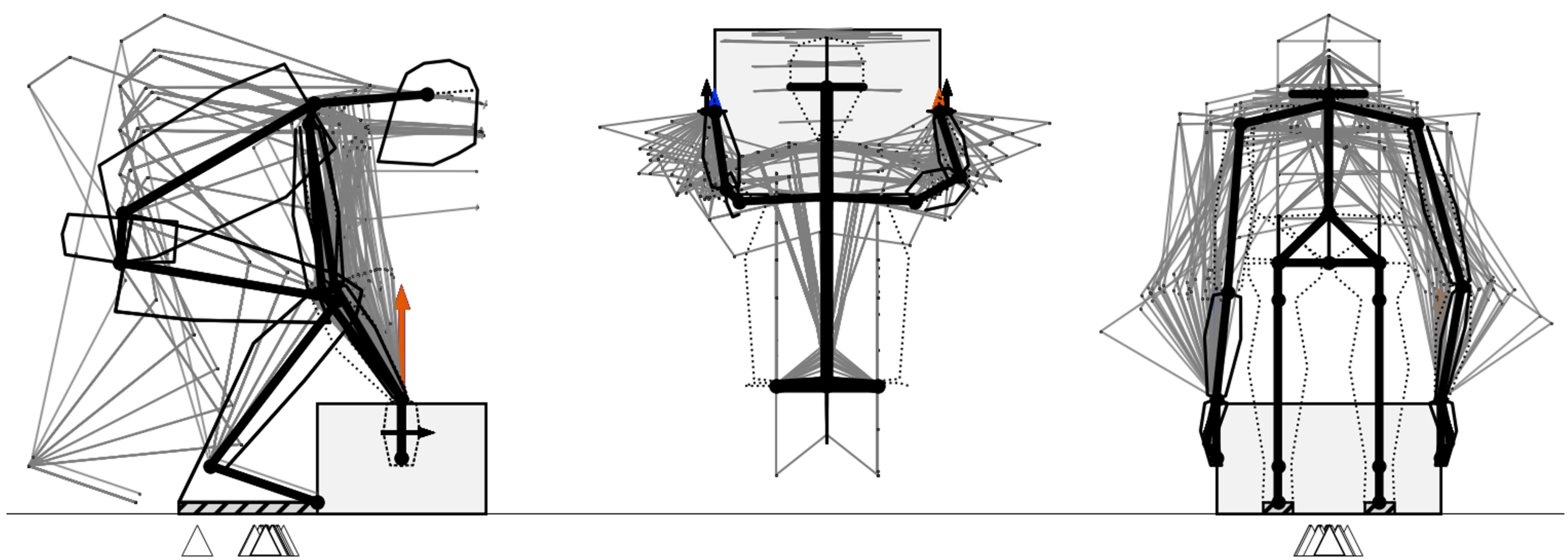
The range of motion of the ankle, knee, hip, lower back, neck, shoulder (including protraction during reaches), elbow, forearm and wrist joints were determined based on a compilation of data from 72 published studies.

Predicting a Full Range of Feasible Postures

Work(s) uses our InteliPose™ method to determine a full range of feasible postures for each task, given the selected body mass percentile and stature percentile. The range of postures is determined by the hands' orientation, grip/pinch interface, and location relative to the middle of the ankles and that is combined with the hand force magnitudes and directions. All posture analyses are performed first with the pelvis height associated with upright, straight legs and then with additional combinations of lower pelvis heights and knee flexions, as well as anterior/posterior spreads of the right and left feet. We also evaluate postures with anterior and posterior displacement of the body. Once the pelvis location is established, we eliminate upper body postures that do not allow for the hands to reach the specified contact locations, then simulate a full range of combinations of low back, shoulder, elbow, forearm, and wrist postures. For each posture, once the trunk orientation and location are established, the neck posture is defined by the focal target (if defined by the user).

Posture and force combinations are eliminated if they result in (1) the overall center of pressure being outside the base of support, and/or (2) at least one segment surface marker that penetrates one of the barriers, and/or (3) at least one joint posture that exceeds a joint's range of motion constraints. For each task, what results from our InteliPose™ method is often a set of tens of thousands of feasible postures - even with the constraints in place - highlighting the potential validity and reliability issues with most current ergonomics processes that typically rely on only one (or sometimes two) postures to solely represent the risk associated with a task.

The figure below illustrates a sample of 50 postures, out of a total of 26,653 feasible postures, for a task where a box lift is initiated from the ground. Note that a barrier was created to represent the box. Views are from the right (left), above (middle) and behind (right). Most postures are shown in grey, but one posture is shown with thicker black lines and the full segment shapes.



Ergonomics Assessments

Based on the total number of feasible postures for a task, we randomly sample a subset of postures according to the Dvoretzky–Kieffer–Wolfowitz inequality (Dvoretzky et al., 1956). The size of the posture subset considers the trade-off between speed and accuracy, but we use enough postures to ensure the accuracy of the calculated DCR values. It should be noted that multiple runs of the same inputs will result in the same total number of feasible postures, but with the random sampling method used, there will be slight differences in the DCR values and images with each run. Each sampled posture is assessed with the tools described below. However, if the overall DCR is between 0.95 and 1.05, we randomly sampled again with 100 times more postures to ensure that the exact DCR values are calculated for the sake of determining overall task acceptability,

Hand, Wrist & Forearm Demands

For the distal upper extremities, Work(s) fully integrates the four push and pull modules of the HandPak™ software package (Potvin Biomechanics Inc., Tecumseh, Ontario, Canada). HandPak™ quantifies acceptable forces for occupational tasks placing demands on the forearms, wrists, hands and fingers, based on an integration of data from 32 published studies. The HandPak™ modules incorporated into Work(s) are (1) pulls with finger(s), (2) pushes with the finger(s) or thumbs, (3) pushes or pulls with pinch grips, and (4) pushes or pull with hand grips. Strengths are predicted based on factors such as location of contact on the finger(s)/thumb(s), glove use, finger clearance, interface characteristics, types of pinch/grip, aperture/span, surface type, direction of effort, wrist posture, elbow posture and shoulder posture. Those maximum strengths are further corrected using the duty cycle, from the frequency and duration of efforts, as input for the Maximum Acceptable Effort (MAE) Equation (Potvin, 2012) to calculate the maximum acceptable forces. In v1.1, we've now included HandPak analyses for power grip strength when the force is acting along the palm towards the wrist (eg. when the hands are hanging down and lifting up on a handle, or are horizontal and pulling). The Hand/Wrist/Forearm Demand/Capacity Ratios (DCRs) are calculated for the left and right sides by dividing the linear forces applied at each hand by their maximum acceptable forces from HandPak™. Use this link to access the HandPak™ web page, a Demo version of the software and the user manual for more details.

Arm Demands

To predict manual arm strength, Work(s) uses the Arm Force Field (AFF) method of La Delfa & Potvin (2017). To develop the AFF, female manual arm strengths were measured directly for up to 26 directions in 36 unique hand locations relative to the shoulder (536 conditions, 13,460 experimental trials). The resulting artificial neural network required only inputs of trunk and arm posture, hand location, force magnitude and force direction to predict manual arm strength and resulted in an overall RMS of only 6.4 N (1.4 lbs). The strengths from the AFF are further corrected using the duty cycle as input to the MAE Equation (Potvin, 2012) to calculate the maximum acceptable forces.

The Arm DCRs are calculated for the left and right sides by dividing the linear forces applied by each arm by their maximum acceptable forces from the AFF. Use this link to download the La Delfa & Potvin (2017) publication describing the AFF method in much more detail.

While the AFF accounts for maximum manual arm strength and the MAE Equation accounts for the fatiguing effects of duty cycle, the Above-Shoulder correction was developed by Rempel & Potvin (2022) to account for the additional risk factor of subacromial impingements of the supraspinatus muscle tendon when the upper arm rotates up above the shoulder. Since this is a new method, Work(s) includes it as an option in Step 7. Download Rempel & Potvin (2022) for more details.

Neck Demands

Flexion and extension neck strengths were estimated from a compilation of data from 5 published studies (Harms-Ringdahl & Schuldt, 1988; Jordan et al. 1999; Queisser et al. 1994; Seng et al., 2002; Vasavada et al., 2001) and corrected using the duty cycle input in the MAE Equation (Potvin, 2012) to calculate the maximum acceptable neck moment.

The Neck DCR is then calculated by dividing the neck flexion or extension strength demand by the maximum acceptable neck flexion or extension moment. Note that a more comprehensive neck analysis package is in the "work(s)", including head-mounted loading and postural effects on strength, fatigue and discomfort.

Lumbar Joint Loading – Biomechanical Criterion

L5/S1 Peak Compression and Shear Force Demand: Peak lumbar compression and shear forces are important risk factors for WMSDs (Waters et al., 1991; Dempsey, 1998; Gallagher & Marras, 2012). For Work(s), the reaction forces (directly caused by the body segment weights and forces at the hands) are calculated at the L5/S1 joint then partitioned into shear and compression force components, assuming that the L5/S1 surface is rotated 34 deg forward of the anterior line perpendicular to the trunk (Gelb set al, 1995). The internal contribution of muscle forces to L5/S1 compression force are estimated with a method developed to estimate the single-equivalent moment arm with a 3rd order polynomial regression equation using the L5/S1 flexion/extension, lateral bend and axial twist moments as inputs (r^2 = 0.87, RMS error = 0.004 m, n = 89). The muscle compression is calculated with the resultant moment of force at L5/S1 divided by the single-equivalent moment arm estimate, and this is added to the compression component of the reaction force to calculate the total bone-on-bone compression force at L5/S1 (r^2 = 0.95, RMS error = 342 N, n = 89).

Lumbar Peak Compression Force Limits: Jäger (2023) summarized the raw compression strength data from 510 lumbar spine specimens (205 female, 305 male) (see his Table 5.12 on p 547–569). We analyzed these data to estimate the mean and standard deviation of the ultimate strength (US) for the L5/S1 joint of females and males for any age from 20 to 70 years. The calculations in Work(s) are based designing for 42 years of age, as that is the mean age of North American labourers. The yield point was set at 82% of the compression ultimate strength based on Yoganandan et al. (1989), such that the peak compression force limits were 3,500 and 4,364 N for females and males, respectively. The Peak Lumbar Compression DCR is calculated by dividing the peak lumbar compression force by the relevant peak compression force limit.

Lumbar Compression Force Cumulative Damage Force: In v1.1, we've added a calculation of lumbar compression force cumulaitve damage (LCF_{CD}) for each task based on a new method developed by Work(s) Ergo Inc., using the raw data of Brinckmann et al. (1988), who tested a total of 70 joints (from 35 specimens) with repetitive loads up to 5,000 cycles to failure (C2F). Load magnitudes were set based on assumptions of ultimate stress (US). We used a Weibull analysis to determine representative C2F values for the following four ranges: 50-60, 60-70, 70-80, 80-90 %US. A function was then computed to transform the average of the peak %US values from each range so that, when multiplied by the C2F, the product was 1.00, which was set to be the threshold limit value (TLV). The resulting equation estimates the LCF_{CD} for any combination of (1) frequency (F), and (2) peak lumbar compression force represented as a percentage of the relevant ultimate strength (%US). Values >1.00 are unacceptable and LCF_{CD} values can be summated across tasks to calculate an overall LCF_{CD}. The overall lumbar compression DCR is calculated as the maximum of the peak compression DCR and LCF_{CD} DCR. Note that our analysis of the Brinckmann data indicated that no cumulative damage results from peak compression forces ≤47% of the ultimate strength.

Manual Materials Handling – Psychophysical Criterion

The Liberty Mutual Insurance psychophysical data of Snook (1978) was an important foundation of the original NIOSH Lifting Equation (NIOSH, 1981). After the tables were updated by Snook & Ciriello (1991), they were incorporated into the Revised NIOSH Lifting Equation (Waters et al., 1993). After 1991, there were no more published updates to the Snook & Ciriello Tables, but manual materials handling research continued at the Liberty Mutual Center for Safety & Health and Vince Ciriello published 12 more studies, with the last in 2011. These data were combined with that from the previous 7 publications used for the Snook & Ciriello Tables (19 publications, 388 unique conditions, 1,788 trials) to create the Liberty Mutual Manual Materials Handling (LM-MMH) Equations published in Potvin, Ciriello, Snook, Maynard, Brogmus, (2021). The resulting 14 equations (7 each for females and males) are integrated into Work(s) to calculate maximum acceptable loads for lift, lower, push (initiate and sustained), pull (initiate and sustained) and carry tasks. Download Potvin et al., (2021) for more details.

The LM-MMH Equation DCR is calculated by dividing the total force at the hands by the maximum acceptable load. For push and pull tasks, the DCR is calculated as the higher of the initiate DCR and sustained DCR.

Integrating Demand/Capacity Ratios

For each feasible posture determined for a given task, Work(s) calculates 7 DCRs, including the lumbar compression force, neck demands, LM-MMH Equation, as well as the left and right hand/wrist/forearm and manual arm demands. An Overall DCR is also calculated for each posture, representing the highest (ie. weakest link) of the 7 DCRs. This provides a single value to represent the risk for each posture and, using the DCR Percentile cutoff set by the user, this can also provide a single value to represent the risk for all feasible postures for a given task. Appendix 1 provides an example of how the Overall DCR would be calculated from 2 of the 7 variables (right arm and lumbar compression force), to illustrate this concept.

Combining Multiple Subtasks

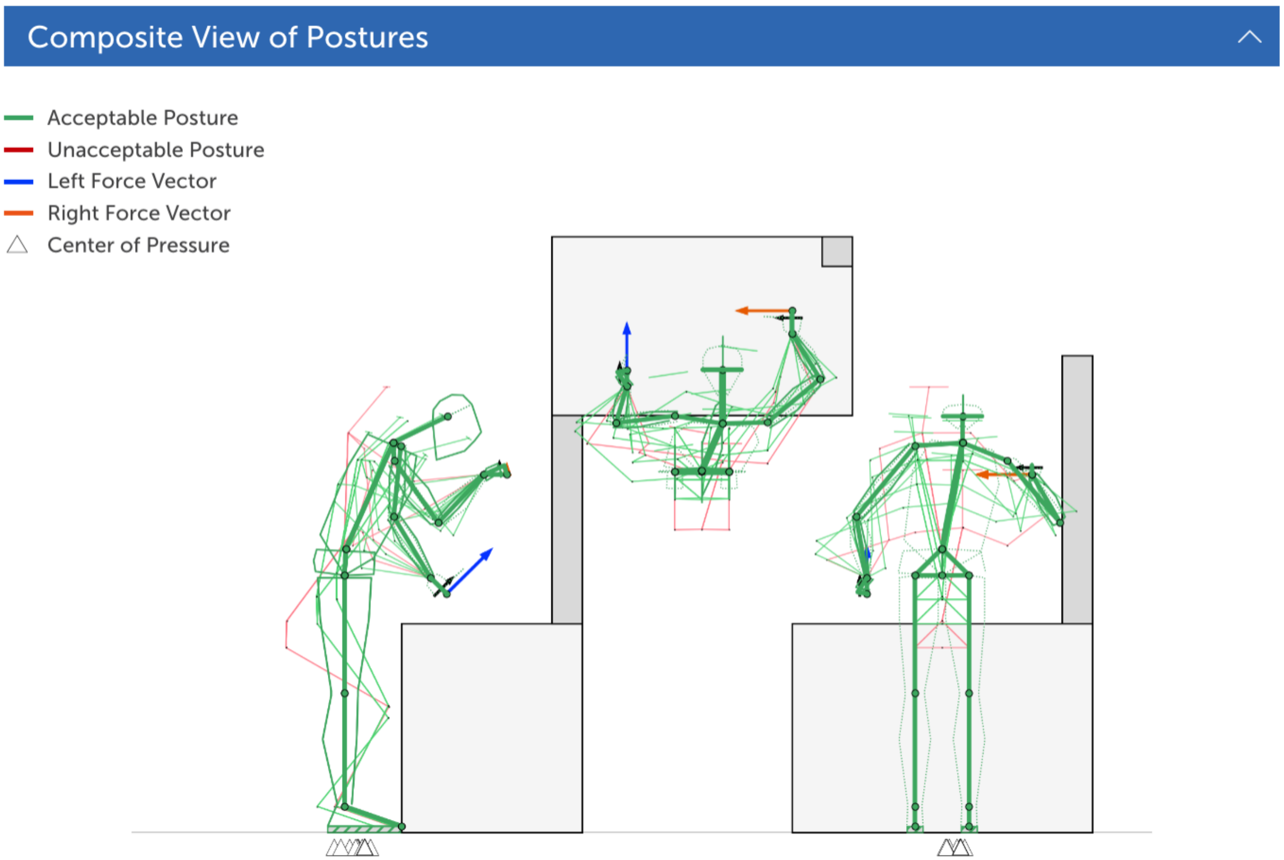
Work(s) is designed to assess individual tasks, with specific hand locations, force characteristics, frequency, and effort duration. However, many jobs include multiple subtasks and confirming that each task is acceptable in isolation does not confirm that the combination of all subtasks is also acceptable. Gibson & Potvin (2016) developed the Recommended Cumulative Recovery Allowance (RCRA) method to allow for the combination of risk across tasks placing demands on similar muscle groups. They rearranged the MAE Equation to solve for recovery allowance, when effort, frequency and effort duration are known, such that the recovery allowance from each subtask can be summated across task to ensure that the total recovery duration needed is not greater than the recovery duration provided (after the total effort duration is accounted for). We've replaced the RCRA method with a new variable to calculate "Cumulative Fatigue", which has a TLV of 1.00 and is easier to interpret and more intuitive than the RCRA, but results in the same decision of acceptable/unacceptable within isolated tasks and across multiple subtasks In addition, the Cumulative Compression values are compiled in the Report so they can be combined in a "**Work(s) - Cumulative Risk Analysis**" Excel template file which can be obtained on request. This is explained in more detail in the "Exported Excel Report" section.

Website Output Interface

There are two modes of output when a task assessment is run in Work(s). The first is the website output pages and the second is an Excel Work(s) Report file that can be exported to the user's hard drive (explained below). The following website outputs are presented for each assessment.

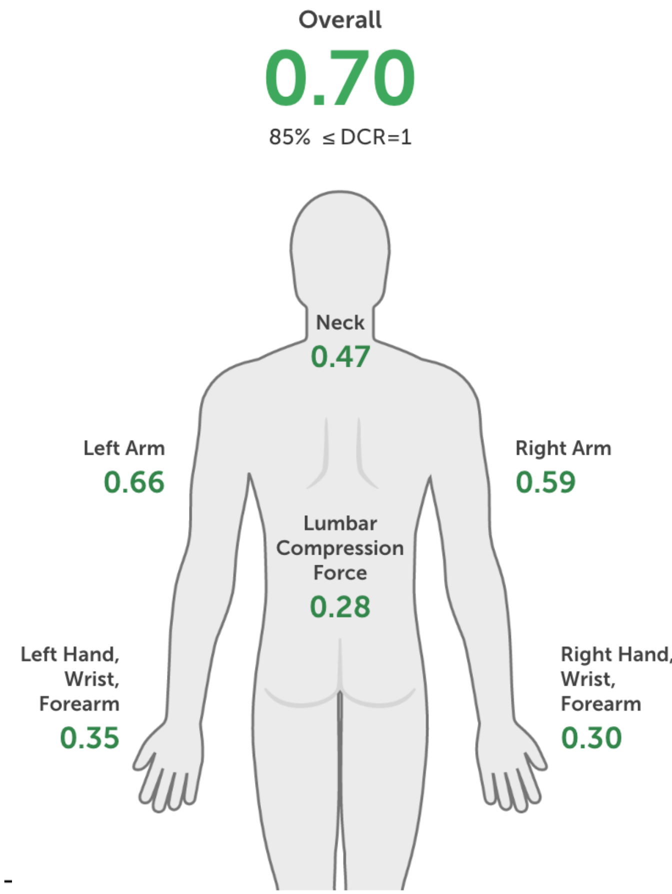
Composite View of Postures

After clicking the "View Outputs" button, the Work(s) Outputs page is presented on the website. The first section shows three views of postures associated with Overall DCRs at the 10th to 90th percentile (in increments of 10%) and at the DCR Percentile selected by the user in Step 1 (25th in this example), shown with segment shapes and thicker lines. Postures with an Overall DCR ≤ 1.0 are shown with green lines and those with an Overall DCR > 1.0 are shown with red lines. A view from the right is shown on the bottom left, a view from above is shown in the middle and a view from behind is shown on the right. The black arrows on the hands indicate the knuckle line directions, the blue arrow indicates the left hand's force direction, and the orange arrow indicates the right hand's force direction. The centers of pressure are shown as triangles under the feet. Barrier #1 is shaded in lighter grey and Barrier #2 is shaded in darker grey.



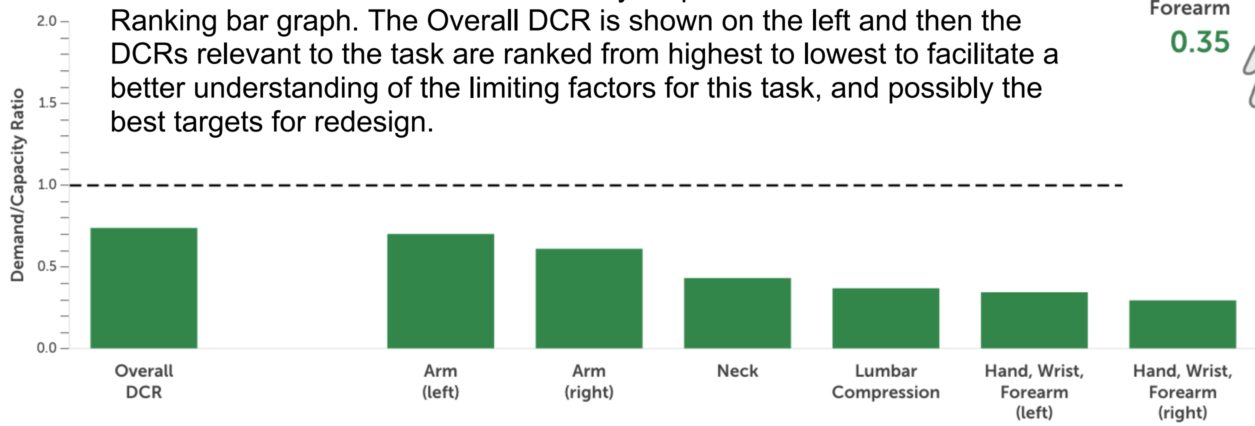
Body Map of Demand/Capacity Ratios (DCRs)

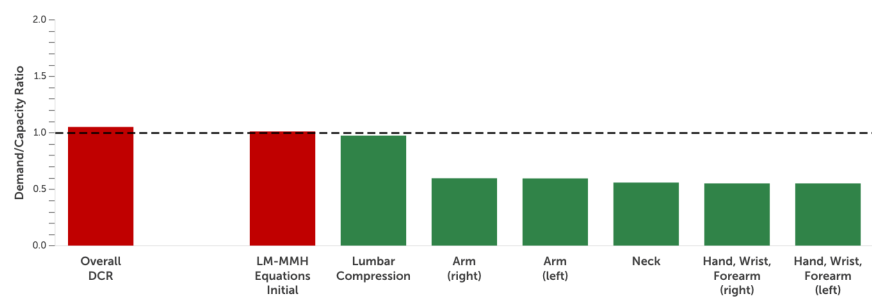
For each task, there will be a range of DCR values for each risk variable. The DCR Percentile cutoff set in Step 1 determines the DCR value that will represent each risk variable. We recommend that the 25th percentile be used as the and that is what is used in this example. The DCRs at the percentile cutoff are then presented on the body map shown to the right. As explained in Appendix A, the Overall DCR at the DCR Percentile cutoff will often be higher than the highest of the DCRs across the risk variables. In this case, the highest individual DCR is 0.66 for the Left Arm, but the 25th percentile Overall DCR is higher at 0.70. In addition, Work(s) determined that 85% of the 84,319 postures assessed for this task had Overall DCR values ≤ 1.0, and this variable may prove to be a valuable metric for assessing the risk for tasks across the full range of feasible postures. Note that this sample task was a static exertion. Manual materials handling tasks (lift, lower, push, pull and carry) will also have a LM-MMH Equation DCR value below the legs. An example for lifting, with some DCRs > 1.0 and the LM-MMH Equation DCR is shown in the bottom right.

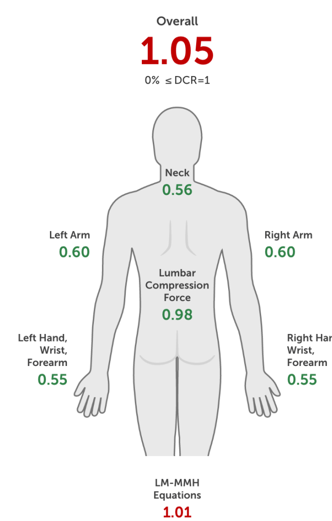


Ranking of Demand/Capacity Ratios

The same data shown on the DCR body map are also shown in the DCR Ranking bar graph. The Overall DCR is shown on the left and then the DCRs relevant to the task are ranked from highest to lowest to facilitate a better understanding of the limiting factors for this task, and possibly the best targets for redesign.







Summary Table

The Summary tab of the Output interface presents the demands for each risk variable (associated with to the DCR Percentile cutoff selected in Step 1), the maximum strength capacities (for a single effort) and the maximum acceptable forces (based on the duty cycle) for Hand/Wrist/Forearm (from HandPak™), the Arm (from the AFF), and Neck. All demands are calculated based on the "D/C Ratio %ile" selected in Step 1 of the Inputs.

Near the bottom of the table, the "Max. Acceptable Total Force" is presented, but only for tasks where the force magnitudes and directions are the same on the right and left hands.

The number of feasible solutions is shown at the bottom of the first column and the joint axis strength demands are shown on the right.

Summary | Results

Analysis Tool Results

Arm (N)	Left	Right
Demand	35.0	30.0
Strength	84.8	77.8
Max. Acceptable Forces	53.0	49.7

Hand, Wrist & Forearm (N)	Left	Right
Demand	35.0	30.0
Strength	161.5	161.5
Max. Acceptable Forces	101.1	101.1

Low Back (L5S1 Joint) (N)	
Shear Force Resultant Demand	183
Compression Force Demand	1,086
Max. Compression Strength	3,856
Cumulative Compression Demand	0
Cumulative Compression TLV	1

Neck (Nm)	
Resultant Demand	7.2
Max. Resultant Strength	25.9
Max. Acceptable Torque	16.2

Liberty Mutual MMH Equations (N)	
Demand	65.0
Max. Acceptable Load	NA

Total Force (N)	
Total Force	65.0
Max. Acceptable Total Force	NA

Feasible Simulated Postures	84,319

Joint Strength Demands (Nm)

Joint	-/+	Left	Right
Wrist	Ext / Flex	-0.1	-0.2
	RD / UD	-2.6	-2.1
	Sup / Pro	-1.1	-0.9
Elbow	Ext / Flex	3.6	1.9
Shoulder	Ext / Flex	-3.8	9.1
	AD / AB	5.8	-2.7
	Int / Ext	3.1	-1.6
Neck	Ext / Flex		-6.8
	L / R Lat		-1.1
	R / L Twist		0.1
L5S1	Ext / Flex		-43.0
	L / R Lat		6.9
	R / L Twist		3.7

Summary Table: Push & Pull

The Summary tab for "Push & Walk" and "Pull & Walk" tasks is shown, and now includes a more complete assessment of both the Initial and Sustained phases. Only the total demands, strengths and acceptable forces are shown, combining the right and left arms.

Summary | Results

Analysis Tool Results

Arm (N)	Initial	Sustained
Demand	150.0	100.0
Manual Arm Strength	374.5	374.5
Max. Acceptable Force	239.0	134.6

Hand, Wrist & Forearm (N)	Initial	Sustained
Demand	150.0	100.0
Maximum Strength	312.1	312.1
Max. Acceptable Force	195.4	105.7

Low Back (L5S1 Joint) (N)	
Shear Force Resultant Demand	318
Compression Force Demand	1,135
Max. Compression Strength	3,856
Cumulative Compression Demand	0
Cumulative Compression TLV	1

Neck (Nm)	
Resultant Demand	0.8
Max. Resultant Strength	26.1
Max. Acceptable Torque	8.1

Liberty Mutual MMH Equations (N)	Initial	Sustained
Demand	150.0	100.0
Max. Acceptable Load	197.4	103.8

Total Force (N)	
Total Force	150.0
Max. Acceptable Total Force	197.4

Feasible Simulated Postures	3,704

Joint Strength Demands (Nm)

Joint	-/+	L/R Mean
Wrist	Ext / Flex	-0.2
	RD / UD	0.0
	Sup / Pro	0.0
Elbow	Ext / Flex	1.2
Shoulder	Ext / Flex	-5.1
	AD / AB	-1.5
	Int / Ext	-0.7
Neck	Ext / Flex	-0.8
	L / R Lat	0.0
	R / L Twist	0.0
L5S1	Ext / Flex	-58.9
	L / R Lat	0.2
	R / L Twist	0.1

Exported Excel Report

On the Outputs interface page, there is an option to export and Excel Report file. This report file contains a summary of the inputs and the outputs from the website, but also includes a graph of all DCRs for each risk variable and a Summary sheet containing a table with all inputs and outputs.

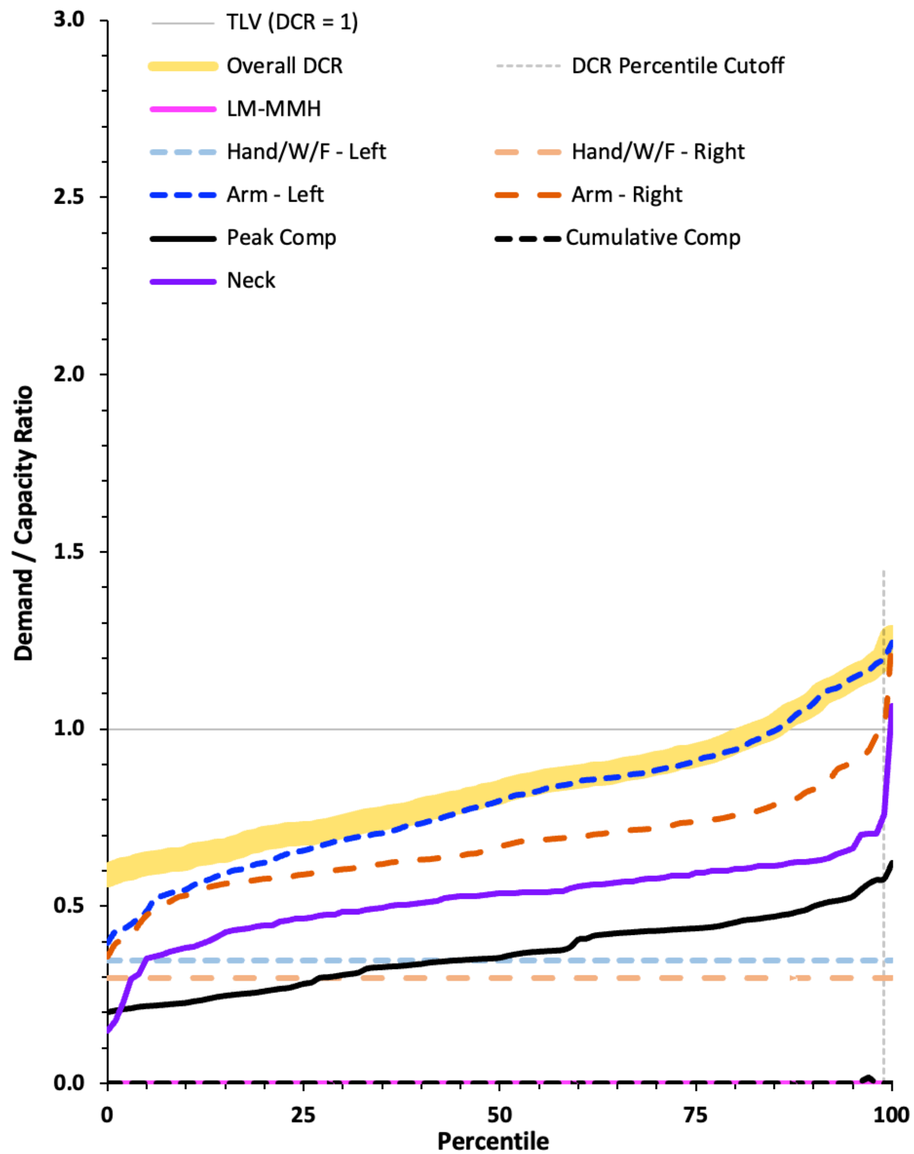
DCR Graph

This graph shows the distribution of DCR values from 0 to the 100th percentile for the sample task used above. DCRs for each of the 6 relevant variables, in addition to the Overall DCR (in yellow), are shown ranked from lowest on the left (0 percentile) to highest on the right (100th percentile). LM-MMH Equation DCRs are not calculated for static exertions.

The TLV line is horizontal and set at a threshold of DCR = 1.0.

The DCR Percentile cutoff set in Step 1 is shown as a vertical dotted line. The values in the body map are based on where each DCR curve crosses this line.

The table below shows the 0 (minimum), 25th (cutoff) and 100th (maximum) DCR values for each risk variable.



	Percentile		
	0 (Min)	25	100 (Max)
Hand/Wrist/Forearm - Left	0.35	0.35	0.35
Arm - Left	0.40	0.66	1.25
Hand/Wrist/Forearm - Right	0.30	0.30	0.30
Arm - Right	0.36	0.59	1.26
Lumbar Compression	0.20	0.28	0.62
Neck	0.15	0.47	1.06
Overall DCR	**0.59**	**0.70**	**1.26**

For this sample task, the right arm has the highest DCRs at the lowest percentiles, but the left arm has the highest DCRs after that. At the 25th percentile, the Overall DCR is **0.70** (acceptable) and the left arm DCR is 0.66 (as shown above on the body map). The Overall DCR is acceptable at the 25th percentile cutoff but does get as high as 1.26 at its maximum.

Summary Sheet

In the exported Excel Work(s) Report file, there is a Summary sheet that compiles all the inputs and outputs into one column. An example from the sample task is shown below (but as two columns so they can be included here on one page).

First there is a summary of all Inputs, then all the calculated Demands, then Capacities, then DCRs, then some other information from the analysis at the bottom. The data from multiple tasks can be compiled into the "**Work(s) - Database of Report Summaries**" Excel template file available on request. Variable code names are provided if pivot tables are used with the compiled data.

A full description of this process is provided at the end of the '**Work(s) Tutorial - Report File**' video available in the '**Work(s) Resources**' Google Drive.

Category		Variable	Code	Units	Values
Inputs	Target Population	Task ID	TaskID		Subtask #1
		Sex	Sex		Female
		Units	Units		Metric
		DCR %ile	DCR%ile		25
		Body Mass %ile	BodyMass%		50
		Body Mass	BodyMass	kg	73.5
		Stature %ile	Stature%		50
		Stature	Stature	m	1.6
		Percent Capable	%Cap	%	75
		Age	Age	years	42
	Task Type	Task Type	TaskType		Lift Load
		Frequency per Day	Freq	/day	630.0
		Effective Duration Entered	Effect-Dur-Input	s	0.922
		Task Distance	TaskDist	m	0.000
		Hip Height	HipHt	m	0.000
		Shift Duration	ShiftDur	hours	8
	Barriers	Barrier #1?	B1		Yes
		Depth	B1-Depth	m	0.300
		Top Edge	B1-Top	m	0.150
		Left Edge	B1-Left	m	-0.150
		Right Edge	B1-Right	m	0.150
		Bottom Edge	B1-Bottom	m	0.000
		Barrier #2?	B2		No
		X Offset	B2-Xoffset	m	N/A
		Depth	B2-Dept	m	N/A
		Top Edge	B2-Top	m	N/A
		Left Edge	B2-Left	m	N/A
		Right Edge	B2-Right	m	N/A
		Bottom Edge	B2-Bottom	m	N/A
	Contact Locations	Left Arm Off?	LeftOff		No
		Left X Location	HCL-T-X-L	m	0.150
		Y	HCL-T-Y-L	m	0.850
		Z	HCL-T-Z-L	m	-0.180
		Left X Bottom	HCL-B-X-L	m	0.150
		Y	HCL-B-Y-L	m	0.100
		Z	HCL-B-Z-L	m	-0.180
		Right Arm Off?	RightOff		No
		Right X Location	HCL-T-X-R	m	0.150
		Y	HCL-T-Y-R	m	0.850
		Z	HCL-T-Z-R	m	0.180
		Right X Bottom	HCL-B-X-R	m	0.150
		Y	HCL-B-Y-R	m	0.100
		Z	HCL-B-Z-R	m	0.180
	Force Parameters	Left Direction: X	ForceDir-X-L		0.000
		Y	ForceDir-Y-L		1.000
		Z	ForceDir-Z-L		0.000
		Left Force	Force-L	N	37.5
		Left Sustained	Force-L-S	N	N/A
		Right Direction: X	ForceDir-X-R		0.000
		Y	ForceDir-Y-R		1.000
		Z	ForceDir-Z-R		0.000
		Right Force	Force-R	N	37.50
		Right Sustained	Force-R-S	N	N/A
	Hand Grip & Orientations	Left Hand Task	Task-L		Power Grip (Medial Grasp)
		Knuckle Line	Knuckle-L		Forward
		Palm Direction	Palm-L		Right
		Span/Diameter	Span-L	mm	N/A
		Gloves Used?	Glove-L		N/A
		Surface Type	Surface-L		N/A
		Right Hand Task	Task-R		Power Grip (Medial Grasp)
		Knuckle Line	Knuckle-R		Forward
		Palm Direction	Palm-R		Left
		Span/Diameter	Span-R	mm	N/A
		Gloves Used?	Glove-R		N/A
		Surface Type	Surface-R		N/A
	Analysis Settings	Above-Shoulder?	AboveShld		Yes
		Limit Trunk?	Limit-Trunk		Yes
		Body Bracing?	Body-Brace		None
		Straight Legs?	Lock-Leg		No
		Cumulative Compression?	CumulComp		Yes
		Task Name	TaskID		Subtask #1
		Gaze?	Gaze		None
		X	GazeX	m	N/A
		Y	GazeY	m	N/A
		Z	GazeZ	m	N/A
Demands	Durations	Effective Duration	Effect-Dur	s	0.922
		Effective Duration-Sust	Effect-Dur-S	s	N/A
		Total Duration	Total-Duration	s	580.9
		Total Duration-Sust	Total-Duration-S	s	N/A
		Duty Cycle	UE&S-DC		0.0231
		Duty Cycle-Sust	UE&S-EDS		N/A
	Left Upper Extremity	Wrist -Ext/+Flex	Wrist-FE-L	Nm	-0.10
		-Rad/+Uln	Wrist-UR-L	Nm	0.00
		-Sup/+Pro	Wrist-PS-L	Nm	0.00
		Elbow +Flex	Elbow-L	Nm	1.38
		Shld -Ext/+Flex	Shld-FE-L	Nm	1.15
		-Ad/+Ab	Shld-AB/AD-L	Nm	3.23
		-Int/+Ext	Shld-EI-L	Nm	0.93
		Arm Force	Arm-Force-L	N	37.5
		Arm Force-Sust	Arm-Force-L-S	N	N/A
		Arm Effort	Arm-Effort-L		0.236
		Arm Effort-Sust	Arm-Effort-L-S		N/A
		Hand Force	Hand-Force-L	N	37.5
		Hand Force-Sust	Hand-Force-L-S	N	N/A
		Hand Effort	Hand-Effort-L		0.277
		Hand Effort-Sust	Hand-Effort-L-S		N/A
	Right Upper Extremity	Wrist -Ext/+Flex	Wrist-FE-R	Nm	-0.10
		-Rad/+Uln	Wrist-UR-R	Nm	0.00
		-Sup/+Pro	Wrist-PS-R	Nm	0.00
		Elbow +Flex	Elbow-R	Nm	1.28
		Shld -Ext/+Flex	Shld-FE-R	Nm	-1.16
		-Ad/+Ab	Shld-AB/AD-R	Nm	3.13
		-Int/+Ext	Shld-EI-R	Nm	0.87
		Arm Force	Arm-R	N	37.5
		Arm Force-Sust	Arm-Force-R-S	N	N/A
		Arm Effort	Arm-Effort-R		0.235
		Arm Effort-Sust	Arm-Effort-R-S		N/A
		Hand Force	Hand-Force-R	N	37.5
		Hand Force-Sust	Hand-Force-R-S	N	N/A
		Hand Effort	Hand-Effort-R		0.277
		Hand Effort-Sust	Hand-Effort-R-S		N/A
	Neck (C7/T1 Joint)	Total Duration	Neck-Total-Dur	s	580.9
		Total Duration-Sust	Neck-Total-Dur-S	s	N/A
		Total Duty Cycle	Neck-DC		0.023
		Neck Flx/Ext	Neck-FE	Nm	-7.92
		Lateral	Neck-Lat	Nm	0.00
		Axial	Neck-Ax	Nm	0.00
		Neck Result Mo	Nec-Res-Mo	Nm	7.92
		Neck Effort	Neck-Effort		0.303
		L5S1 Flx/Ext	L5S1-FE	Nm	-144.39
		Lateral	L5S1-Lat	Nm	0.01
		Axial	L5S1-Ax	Nm	0.14
	Lumbar Spine (L5/S1 Joint)	Peak Compression	Pk-Comp	N	2,409
		Peak Compression-Sust	Pk Comp-S	N	N/A
		Overall Peak Compression	Overall-Pk-Comp	N	2,409
		Cumulative Comp	CC		0.56
		Cumulative Comp-Sust	CC-S		N/A
		Overall Cumulative Comp	Overall-CC		0.56
		Peak Shear	Peak-Shear	N	330
		Peak Shear-Sust	Peak-Shear-S	N	N/A
		Overall Peak Shear	Overall-Pk-Shear	N	330
		TBD			
	Hip	Mid Hip Flx/Ext	Mid Hip-FE	Nm	-163.06
		Lateral	Mid Hip-Lat	Nm	0.12
		Axial	Mid-Hip-Twist	Nm	-0.06
	Manual Materials Handling	LM-MMH Force	LM-MMH-Load	N	75.00
		LM-MMH Sustained Force	LM-MMH-S	N	N/A
		TBD			
	CofP	-Back/+Forward Min	CofP-BF-Min	m	N/A
		-Back/+Forward Max	CofP-BF-Max	m	N/A
		-Left/+Right Min	CofP-LR-Min	m	N/A
		-Left/+Right Max	CofP-LR-Max	m	N/A
Capacities	Maximum Accept. Effort	MAE	MAE		0.596
		Neck MAE (Push/Pull)	Neck-MAE		N/A
		MAE-Sust	MAE-S		N/A
	Left Upper Extremity	Arm Strength	Arm-MVC-L	N	160.5
		Arm MAF	Arm-MAF-L	N	95.4
		Arm MAF-Sust	Arm-MAF-S-L	N	N/A
		Hand Strength	Hand-MVC-L	N	135.2
		Hand MAF	Hand-MAF-L	N	80.5
		Hand MAF-Sust	Hand-MAF-L	N	N/A
	Right Upper Extremity	Arm Strength	Arm-MVC-R	N	160.6
		Arm MAF	Arm-MAF-R	N	95.5
		Arm MAF-Sust	Arm-MAF-S-R	N	N/A
		Hand Strength	Hand-MVC-R	N	135.5
		Hand MAF	Hand-MAF-R	N	80.7
		Hand MAF-Sus	Hand-MAF-L	N	N/A
	Neck (C7/T1 Joint)	Neck Strength	Neck-MVC	Nm	26.1
		Neck MAT	Neck-MAT	Nm	15.5
	Lumbar Spine (L5/S1 Joint)	Comp Ultimate Strength	Comp-US	N	4,268
		Peak Comp TLV	Pk-Comp-TLV	N	3,500
		Cumulative Comp TLV	CC-TLV		1.00
		TBD			
		TBD			
	Manual Materials Handling	LM-MMH MAF	LM-MAL	N	127.04
		LM-MMH Sust MAF	LM-S-MAL	N	N/A
		TBD			
	Total	MAF	MAF-Tot	N	127.0
		MAF-Sust	MAFs-Tot	N	N/A
Demand / Capacity Ratios	Overall	Percent ≤DCR = 1	%DCR<1	%	56%
		DCR Overall	DCR-Overall		0.80
	Left Upper Extremity	Arm DCR	Arm-DCR-L		0.40
		Arm DCR-Sust	Arm-DCR-S-L		N/A
		Hand DCR	Hand -DCR-L		0.47
		Hand DCR-Sust	Hand-DCR-S-L		N/A
	Right Upper Extremity	Arm DCR	Arm-DCR-R		0.39
		Arm DCR-Sust	Arm-DCR-S-R		N/A
		Hand DCR	Hand -DCR-R		0.46
		Hand DCR-Sust	Hand-DCR-S-R		N/A
	Spine	Neck DCR	Neck-DCR		0.51
		Peak Comp DCR	Comp-DCR		0.69
		Cumulative Comp DCR	CC-DCR		0.56
		Cumulative Comp DCR-Sust	CC-DCR-S		N/A
		Overall Cumul. Comp DCR	Overall-CC-DCR		0.56
		TBD			
	Manual Materials Handling	LM-MMH DCR	LM-DCR		0.59
		LM-MMH DCR-Sust	LM-DCR-S		N/A
		TBD			
Other		# of CPUs	CPU#		N/A
		Processing Time	Process-Time	min	0.68
		Total Postures	Posures-Total		3227
		Sampled Postures	Postures-Samp		N/A
		Date of Analysis	Date-Analysis		2025-11-02
		Time of Analysis	Time-Analyssi		06:09:09
		Lift/Lower: Top or Bottom Posture?	Top-Botom		Bottom

Summary of Peak and Fatigue Risk Analyses for Each Subtask

To the right of the Summary data is a table that can be used to compile a cumulative risk analysis from multiple subtasks that comprise a full job. This table calculates the duty cycle, MAE, and peak hand/wrist/forearm, arm, and neck efforts, and peak compression forces, as well as the cumulative muscle fatigue, LM-MMH Equations and lumbar compression force cumulative damage DCRs. Note: Push and Pull tasks will have separate rows for the Initial and Sustained phases. Also, this table in highlighted in pink for Lifts and Lowers, and the reason is describled below.

Summary of Data for a Cumulative Risk Analysis

							Muscle Demand DCRs										LM-MMH Eqn. DCR	Lumbar Compression Force DCRs		Overall DCR
							Left				Right				Neck					
							Arm		Hands		Arm		Hands							
Output File Name	Task Type	Units	Effective Duration (s)	Frequency per day	Duty Cycle	Max Accept Effort	Peak Effort	Fatigue	Peak Effort	Fatigue	Peak Effort	Fatigue	Peak Effort	Fatigue	Peak Effort	Fatigue		Peak Comp.	Cumul. Damage	
Subtask #1	Lift Load (Bottom + Top)	Metric	0.922	630	0.0231	0.596	0.360	0.500	0.277	0.466	0.360	0.500	0.277	0.465	0.303	0.303	0.590	0.688	0.563	0.688

Lift or Lower – Combining Data from the Bottom & Top Postures

When a Lift or Lower task is performed, the posture will change from the begininng to the end of the motion. To more accurately capture the peak loads, as well as the accumulation of fatigue and cumulative damage, associated with these changes, we recommend analyzing Lift or Lowers at the Bottom hand location (origin for a lift, destination for a lower) as well as a second Work(s) analysis at the Top hand location (destination for a lift, origin for a lower). To alert the user to the need for this additional step, the "Summary of Data" table is highlighted in pink for Lifts and Lowers. The data from the Bottom and Top hand location analyses can be combined in the "**Work(s) - Lift or Lower - Combine Bottom & Top Postures**" Excel template file (available on request).

Instead of using the table below, the data in the '**Values'** column of the '**Summary'** sheet in the Work(s) Report can be pasted into the "**Work(s) - Lift or Lower - Combine Bottom & Top Postures**" Excel template file to create the "**Summary of Data**" table row shown in the previous section. A full description of this process is provided in the **'Work(s) Tutorial - Lift or Lower - Combine Bottom & Top Postures**' video available in the '**Work(s) Resources**' Google Drive.

Summary of Data for a Cumulative Risk Analysis

							Muscle Demand DCRs										LM-MMH Eqn. DCR	Lumbar Compression Force DCRs		Overall DCR
							Left				Right				Neck					
							Arm		Hands		Arm		Hands							
Output File Name	Task Type	Units	Effective Duration (s)	Frequency per day	Duty Cycle	Max Accept Effort	Peak Effort	Fatigue	Peak Effort	Fatigue	Peak Effort	Fatigue	Peak Effort	Fatigue	Peak Effort	Fatigue		Peak Comp.	Cumul. Damage	
Lift Load - Bottom	Lift Load	Metric	0.922	630	0.0231	0.596	0.236	0.071	0.277	0.089	0.235	0.070	0.277	0.089	0.303	0.104	0.590	0.688	0.563	0.795

Note: The row(s) above (highlighted in yellow) can be pasted into the "Cumulative Risk" sheet of the file called "Work(s) Cumulative Risk Template.xlsx" (available on request by emailing info@worksergo.com) to calculate the cumulative demands and risk from multiple tasks making up a whole job.

Note that, since this is a Lift Load task, a Work(s) analysis should be run for both the 'Bottom' and 'Top' hand locations, so that the values in column G can be pasted into the 'WORK(S) - LIFT or LOWER - COMBINE BOTTOM & TOP POSTURES' Excel worksheet to determine the combined DCR for the whole motion. If you analyze only the 'Bottom' or the 'Top' hand location, you will likely end up with DCR values that either understimate or overestimatethe actual values for the full task.

Cumulative Risk Analysis Across Subtasks

The data from each subtask can be further compiled for a full job using the "**Work(s) Cumulative Risk Analysis**" Excel template file that is available on request. Some sample results are added in addition to the Sample Lift above, including the Initial and Sustained phases of a Push (where the HandPak analyses were not applicable) and a Lower task. The Overall DCRs are calculated by determining the highest of the peak DCRs or summing the fatigue and cumulative damage DCRs in each column, and values >1.00 are considered unacceptable. As all Overall DCR values are <1.00, this full task is considered to be acceptable.

A full description of this process is provided in the '**Work(s) Tutorial - Cumulative Risk Analysis**' video available in the '**Work(s) Resources**' Google Drive.

Work(s)™ Cumulative Risk Analysis

								Muscle Demand DCRs										LM-MMH Eqn. DCR	Lumbar Compression Force DCRs		Overall DCR
								Left				Right				Neck					
								Arm		Hands		Arm		Hands							
	Output File Name	Task Type	Units	Effective Duration (s)	Frequency per day	Duty Cycle	MAE	Peak Effort	Fatigue	Peak Effort	Fatigue	Peak Effort	Fatigue	Peak Effort	Fatigue	Peak Effort	Fatigue		Peak Comp.	Cumul. Damage	
1	Subtask #1	Lift Load (Bottom + Top)	Metric	0.922	630.0	0.0231	0.596	0.360	0.500	0.277	0.466	0.360	0.500	0.277	0.465	0.303	0.303	0.590	0.688	0.563	0.688
2																					
3	Subtask #2	Push & Walk (Init)	Metric	1.000	105.0	0.0042	0.732	0.571	0.141			0.573	0.144			0.123	0.007	0.354	0.622	0.021	0.871
4	Subtask #2	Push & Walk (Sust)	Metric	4.611	105.0	0.0192	0.613	0.322	0.097			0.326	0.100			0.123	0.033	0.307	0.587	0.002	
5																					
6	Subtask #3	Lower Load (Bottom + Top)	Metric	0.560	630.0	0.0140	0.641	0.356	0.450	0.246	0.384	0.356	0.450	0.246	0.384	0.250	0.240	0.457	0.562	0.000	0.562
7																					
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							Overall DCRs	0.571	1.189	0.277	0.849	0.573	1.194	0.277	0.849	0.303	0.583		0.688	0.587	
								1.189		0.849		1.194		0.849		0.583		0.590	0.688		1.194

MAE: Maximum Acceptable Effort
DCR: Demand/ Capacity Ratio
Cumul.: Cumulative

The cumulative risk is Unacceptable

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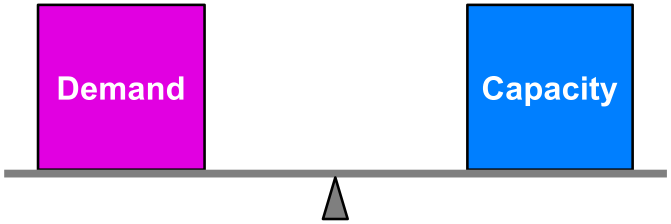
Appendix A: Demand/Capacity Ratios

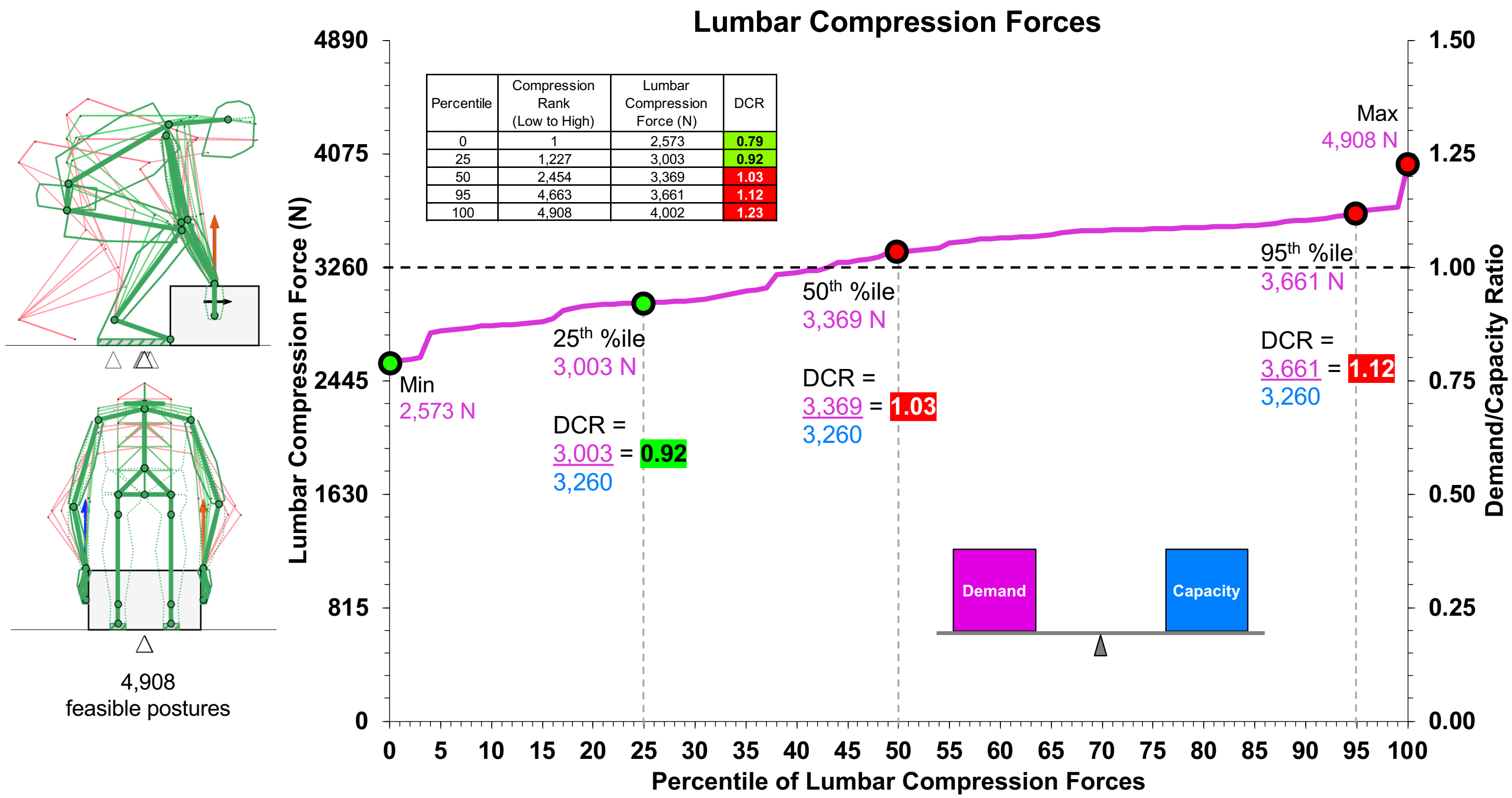
The Demand/Capacity Ratio (ie. "D/C Ratio" or "DCR") is simply the demand of the task divided by the assumed capacity to meet that demand, and it provides a unitless measure of WMDS risk from each of the ergonomics assessment tools in Work(s). The capacity may be based on a single effort strength or could be corrected to account for the fatigue associated with the frequency and effort duration. Unlike most ergonomics software, Work(s) doesn't just assess one task posture, so it will have multiple demands from multiple postures (usually thousands) for any analysis. The DCR Percentile represents the percentile of the DCR values used to determine if the demand for a particular variable is acceptable (≤1.000) or unacceptable (>1.000). We recommend that the 25th percentile DCR be used to represent the risk for each demand variable across the many feasible postures for a given task.

For example, if the lumbar L5/S1 joint compression force demand is estimated to be 3,500 N, and the L5/S1 force capacity is assumed to be 3,260 N (based on data adapted from Jäger (2018) for a 45-year-old female), then the DCR is calculated to be 3,500 / 3,260 = 1.07. Since the demand is greater than the capacity, the DCR is greater than 1.000 and the L5/S1 compression force is considered to be unacceptable. For a lifting task, if the load mass of a lifted box is 10 kg and the LM-MMH Equations (Potvin et al, 2022) estimate the maximum acceptable load (MAL) for a lift to be 13 kg, then the DCR is 10 / 13 = 0.77 and, since the demand is less than the capacity, the DCR is less than 1.000 and the load is considered to be acceptable. Other examples are provided in the table on the right, with acceptable and unacceptable DCRs highlighted in green and red, respectively.



Criterion	Assessment	Units	Demand	Capacity	DCR
Compression	3DSSPP	N	3,500	3,260	1.07
Neck	3DSSPP	Nm	10	22	0.45
Manual Arm Strengths	Arm Force Field	N	75.0	90.0	0.83
- Above-Shoulder	Rempel & Potvin (2022)	N	75.0	65.0	1.15
Hand/Wrist/Forearms	HandPak™	N	75.0	55.0	1.36
Psychophysical	LM-MMH Equations	kg	10	13	0.77
Metabolic Cost	Dempsey Equations	kcal/min	2	3.1	0.65
Cumulative Demands	RCRA	s	18,000	15,000	1.20

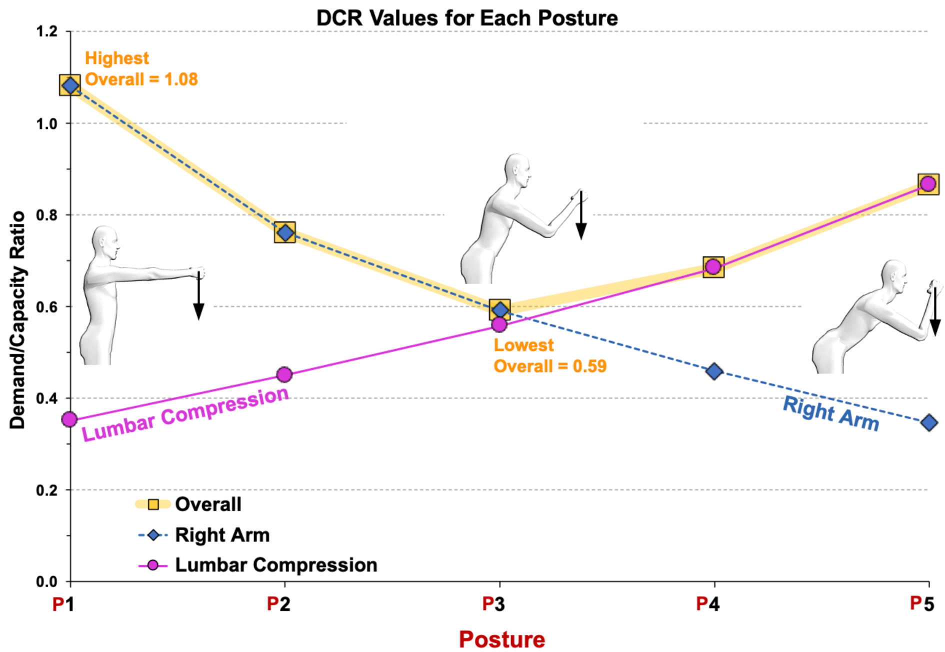
Work(s) is unique in that it doesn't only assess one posture for a task, so it will have multiple DCRs for any assessment tool used. For example, for a lifting task, the L5/S1 compression force will depend on the posture and Work(s) might determine thousands of feasible compression forces for a particular hand location, ranging from the lowest possible magnitude to the highest possible magnitude, and with a distribution of magnitudes (and DCRs) in between. Under such circumstances, one could choose to represent the risk with the lowest DCR (based on an ideal posture for that metric – though it may be improbable, and even not optimal, for a worker to adopt that posture every repetition), the highest DCR (based on a terrible posture that is not likely to ever be adopted by an experienced worker) or something in between. The graphic on the next page shows the range of compression forces and DCRs for the initiation of a lift from the floor.

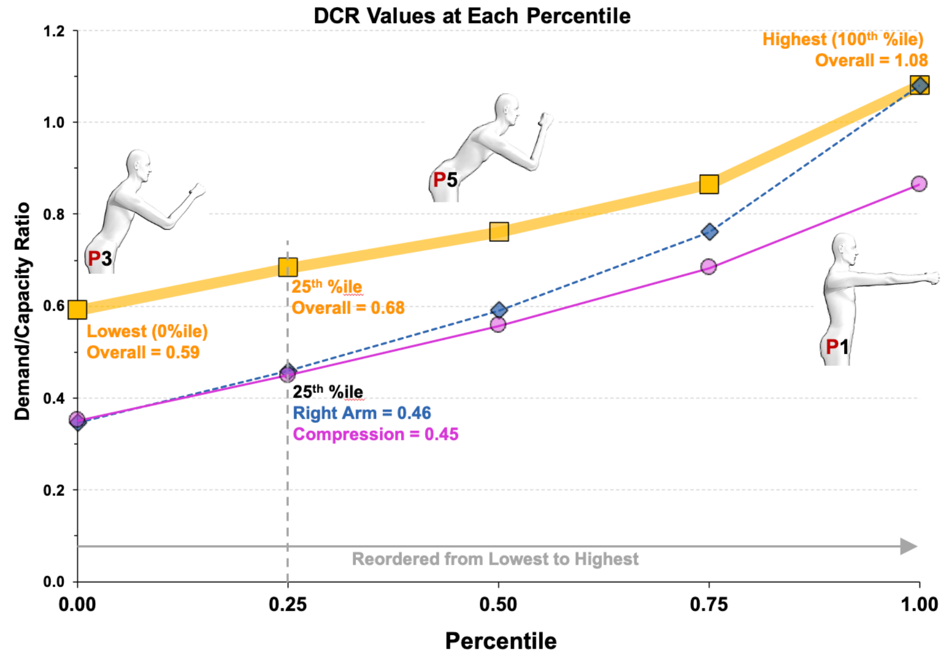


Percentile	Compression Rank (Low to High)	Lumbar Compression Force (N)	DCR
0	1	2,573	0.79
25	1,227	3,003	0.92
50	2,454	3,369	1.03
95	4,663	3,661	1.12
100	4,908	4,002	1.23

This graphic illustrates an example of the DCRs for lumbar compression forces at the initiation of a lift from the floor. Work(s) found 4,908 feasible postures and calculated the compression force for each. They were then sorted from lowest (0 percentile = 2,573 N) to highest (100th percentile = 4,980 N) on the left y-axis and presented as percentiles on the x-axis. Each value can be divided by the lumbar compression capacity (in this case, assumed to be 3,260 N, adapted from Jäger (2018) for a 45-year-old female) to calculate the compression DCR. These are presented on the right y-axis. The 25th, 50th and 95th percentile compression forces (the 1,227th, 2,454th and 4,663rd highest, respectively) were 3,003, 3,369 and 3,661 N, respectively and those convert to DCRs of 0.92 (acceptable), 1.03 (unacceptable) and 1.12 (unacceptable), respectively. Eleven postures are overlaid on the left of the graph, from the side and from behind, for representative postures resulting in the 5th to 95th compression forces, in increments of 5%. We recommend using the 25th percentile DCR to represent the WMSD risk for each variable, and that posture is shown with a full manikin and a bolded stick figure. Postures with a DCR ≤1.000 are in green and those with DCRs >1.000 are in red.

For each posture, a DCR is calculated with each ergonomics assessment tool. Then, within each posture, an Overall DCR is then calculated with the highest DCR across the ergonomics tools (ie. “weakest link”). One might first expect that the Overall DCR curve at each percentile would simply be the highest DCR value at that percentile across the different assessment tools. In other words, the Overall curve would surf across the highest values of the other curves. However, counterintuitively, that is not the case. An example is provided below to illustrate.





Left: This graph shows DCR data from 5 postures of a fictional task, but with only 2 risk variables (right arm & lumbar compression force) and the Overall DCR from those 2 risk variables. Posture 1 has a long reach for the right arm (ie. relatively high right arm demand and DCR of 1.08) but an upright trunk (ie. relatively low lumbar compression force and DCR of 0.35). As we progress from Posture 1 to Posture 5, the trunk becomes more flexed (increasing the lumbar compression forces and DCRs to a maximum of 0.86), but the reach decreases (decreasing the moments of force about the shoulder and elbow and decreasing the right arm DCRs to minimum of 0.35).

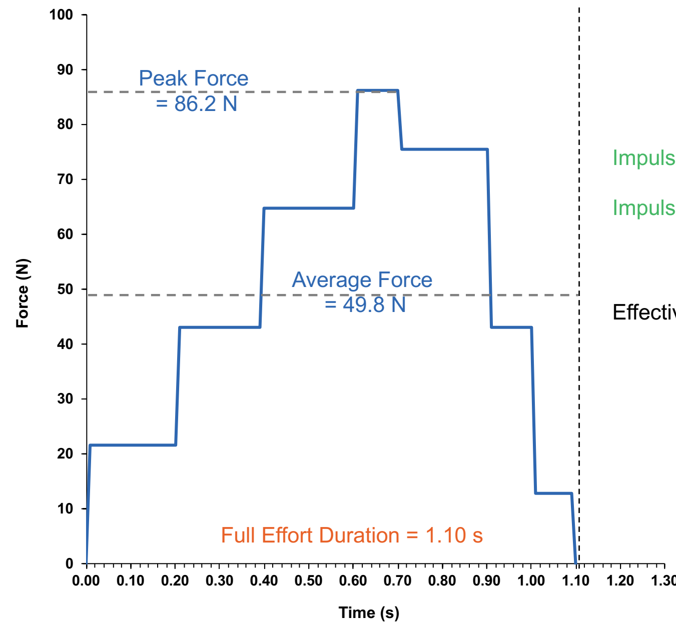
Right: This graph shows the right arm, lumbar compression force and Overall DCRs reordered from lowest (0 percentile) to highest (100th percentile). If we set our DCR Percentile threshold to 25th, then threshold values for the right arm, lumbar compression force and Overall DCRs are 0.46, 0.45 and 0.68, respectively. So, because of the tradeoffs that occur in the DCRs between risk variables, as postures are changed, the 25th Overall DCR will not necessarily be the highest of the 25th percentile values from the various risk variables from the individual ergonomics assessment tools and, in fact, it will often be higher. In other words, the curve with the Overall DCR values at each percentile does not necessarily just surf along the top of the risk variable curves. The Overall DCR is calculated separately for each posture (as shown in the left graph), then it is sorted from lowest to highest on its own curve and the threshold value is determined from that curve (in this example, 0.68, as shown in the right graph).

This concept is described in the “**Work(s) Tutorial - The Demand-Capacity Ratio (DCR)**” video in the ‘**Work(s) Resources**’ Google Drive.

Appendix B: Effective Duration

The Effective Duration represents the best estimate of how long the peak would have to be sustained so that the area under its Effort-Time curve (like an impulse) is the same as that under the actual Effort-Time curve. This does not include the time that the hand may be hovering around the object of exertion (if video is used). It is best to make this estimate from measured force-time curves. It is very important that the effective duration not be overestimated.

The most accurate method to estimate the Effective Duration is to (1) measure the force time-history, (2) estimate the impulse as the average force multiplied by the duration, (3) divide the impulse by the peak force.



Impulse is the area under the force-time curve

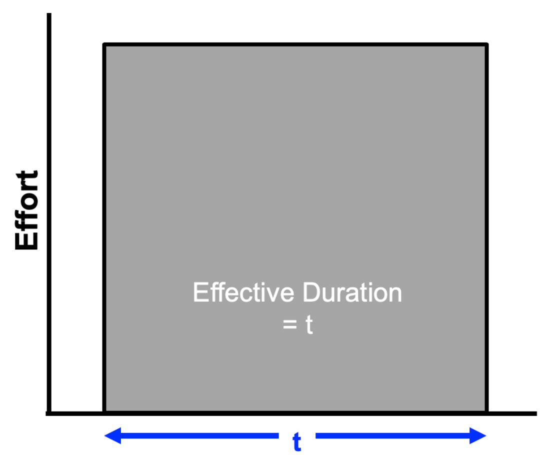
Impulse = (Average Force) (Effort Duration)
= (49.8 N) (1.10 s)
= 54.78 N s

Effective Duration = $\frac{\text{Impulse}}{\text{Peak Force}}$

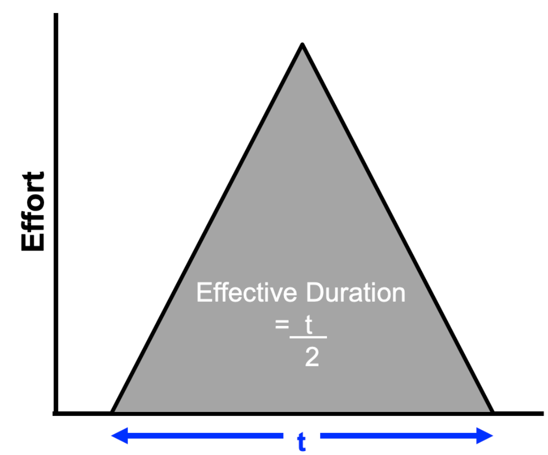
= $\frac{54.78 \text{ Ns}}{86.2 \text{ N}}$ = 0.635 s

If you don't have a force gage that outputs the force time-history, then here are some rules of thumb for estimating Effective Duration.

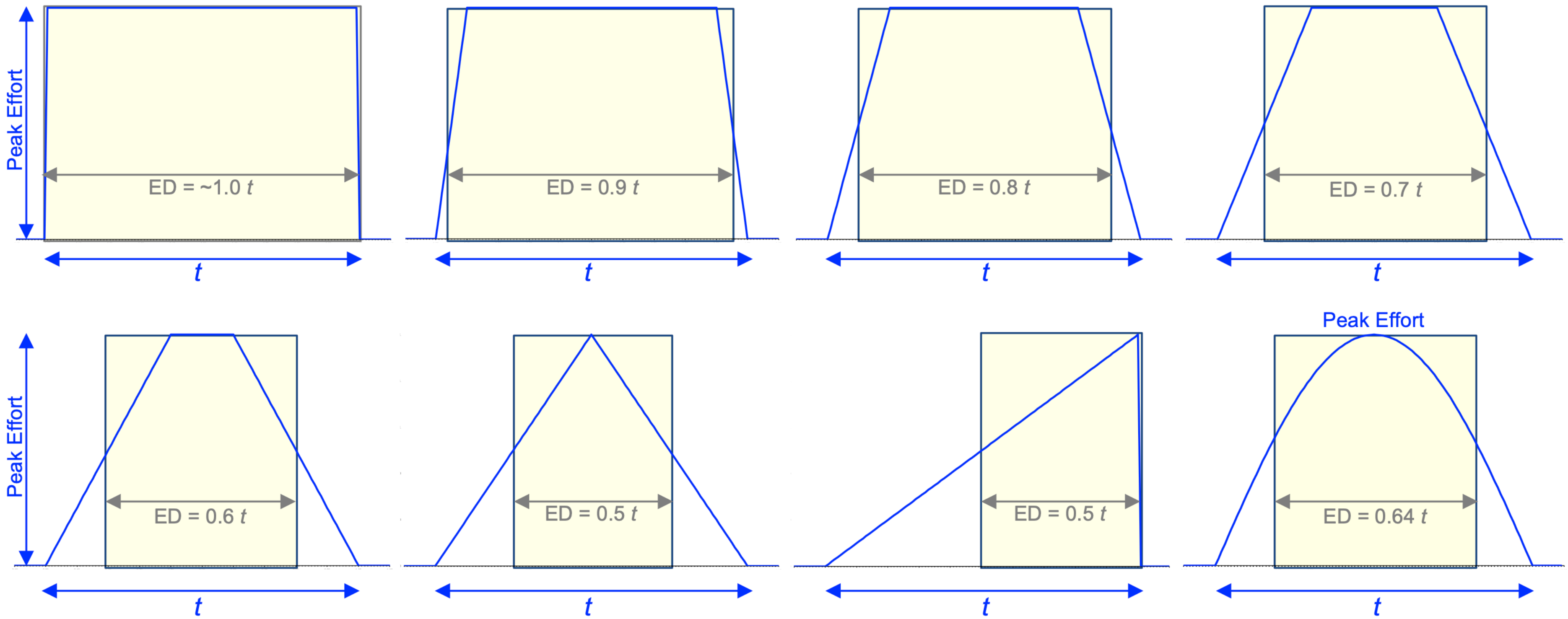
If the Effort-Time curve looks more like this then use "t" as the effective duration



If the Effort-Time curve looks more like this then use "t/2" as the effective duration



Effective Duration (ED) can be estimated based on the shape of the effort time-history. For example, in the bottom left image, there is a slow ramp up, short duration at the peak effort and then slow ramp down. In that case, the impulse (area under the curve) for the full duration of the effort (t) is equal to the peak effort multiplied by 0.6**t**, such that the effective duration for calculating duty cycle would be 0.6**t**.



The Effective Durations of Manual Materials Handling Tasks

The effective durations are required in Work(s) for the manual materials handling tasks as they are used to estimate the maximum acceptable efforts for the neck and upper extremities. These can be difficult to measure or estimate, so we've made some assumptions based on the scientific literature and estimate these durations based on the vertical displacement during lift and lower tasks and the horizontal displacement for push, pull and carry tasks and.

Lift and Lower Tasks:

Based on our own pilot research, we've developed an algorithm to estimate the durations of lift and lowers based on vertical displacement between the Bottom to Top hand contact heights. Assuming lower average velocities for smaller displacements, given the need to accelerate the load at lift/lower initiation, the predicted durations increase from 0.46 s at 0.25 m to 1.67 s at 2.00 m of displacement. These fall within the ranges cited by Lin et al (1999) and Lavender et al (2003). We are collaborating with researchers at Ontario Tech University to further develop and validate these predictions.

Push and Pull Tasks:

We've assumed a Sustained phase of pushing and pulling would have an average velocity of ~2 miles per hour (0.9 m/s) based on a personal communication with Vince Ciriello, as this was never stated in any of the 19 Liberty Mutual publications used for the LM-MMH Equations (Potvin et al., 2021). Based on data from Lee et al (2014), we've estimated that the Initial phase would occur over the first 0.85 m over a duration of 2.00 s.

Carry Tasks:

The average carrying velocity was assumed to be 1.25 m/s based on the walking data of Schimpl et al (2011).