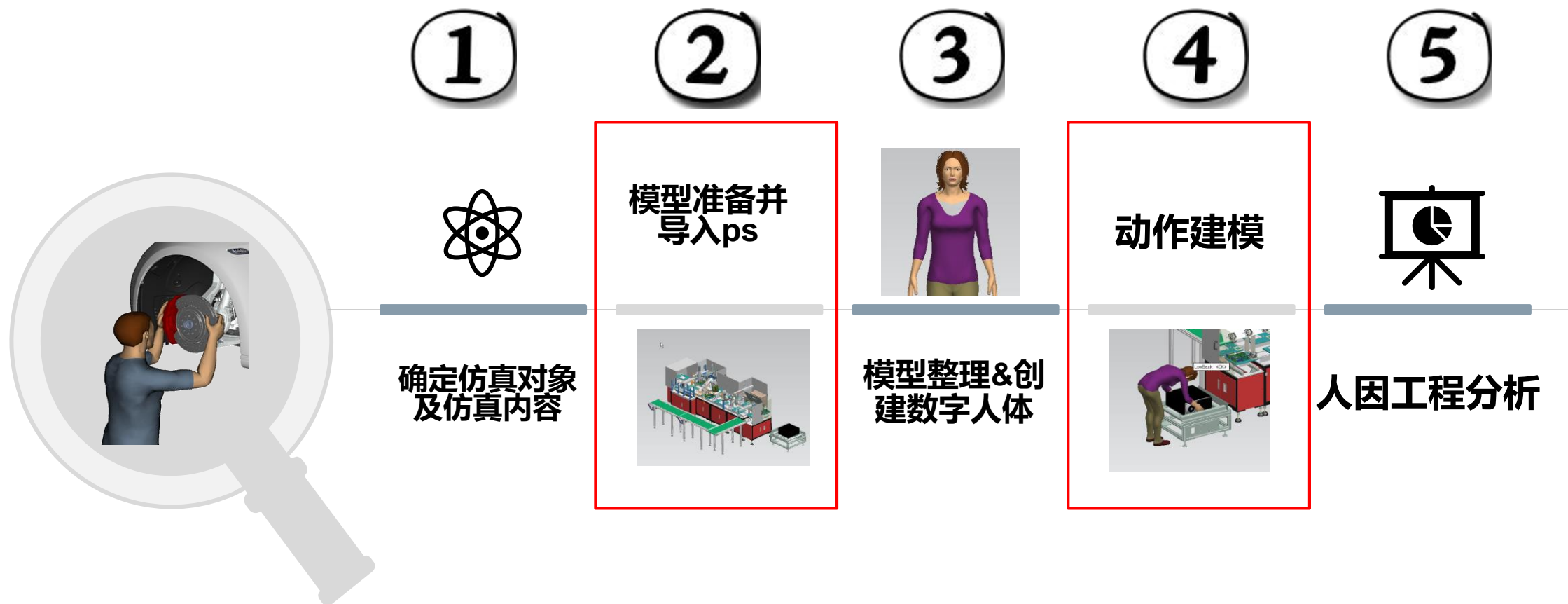


# 人因工程深入应用及人机绩效评价准则

---Process Simulate常用人因分析工具



## TC集成方式

离线方式

The screenshot displays the Siemens Teamcenter Manufacturing Process Planner interface. On the left, a BOM table lists various components and their types. In the center, a table shows test results for different milestones. On the right, a CAD model of a PCB assembly is visible. A 'Run Test in Process Simulate' button is highlighted, and a 'Convert and Insert CAD Files' menu option is shown.

	Last	Run Test in Process Simulate	Milestone
AD	22-Oct-2017 12:...	Passed	
FIE...		No Result	
AD	23-Oct-2017 02:...	Passed	
IATE...	22-Oct-2017 12:...	Failed	
SE		No Result	
SE		No Result	
SE		No Result	
SE		No Result	





Placement Manipulator

Translate: Step Size: 100.00mm  
X Y Z -638.99

Rotate: Step Size: 10.00deg  
Rx Ry Rz 0

Frame of Reference: Geometric center

Initial manipulator position: Geometric center

Reset Close

Create Frame

Align X  
Align Y  
Align Z  
Align -X  
Align -Y  
Align -Z  
Distribute X  
Distribute Y  
Distribute Z

Relocate

Relocate Properties

Objects  
dangbanheji.prt

From frame: Self

To frame: Geometric center

Copy object  
Maintain orientation  
Translate only on: X Y Z

Flip

Boots & Gloves

Sole height: 2.54 (cm)

Glove thickness: 1.00 (mm)

Load parameters from .fig file

OK Cancel

工程分析

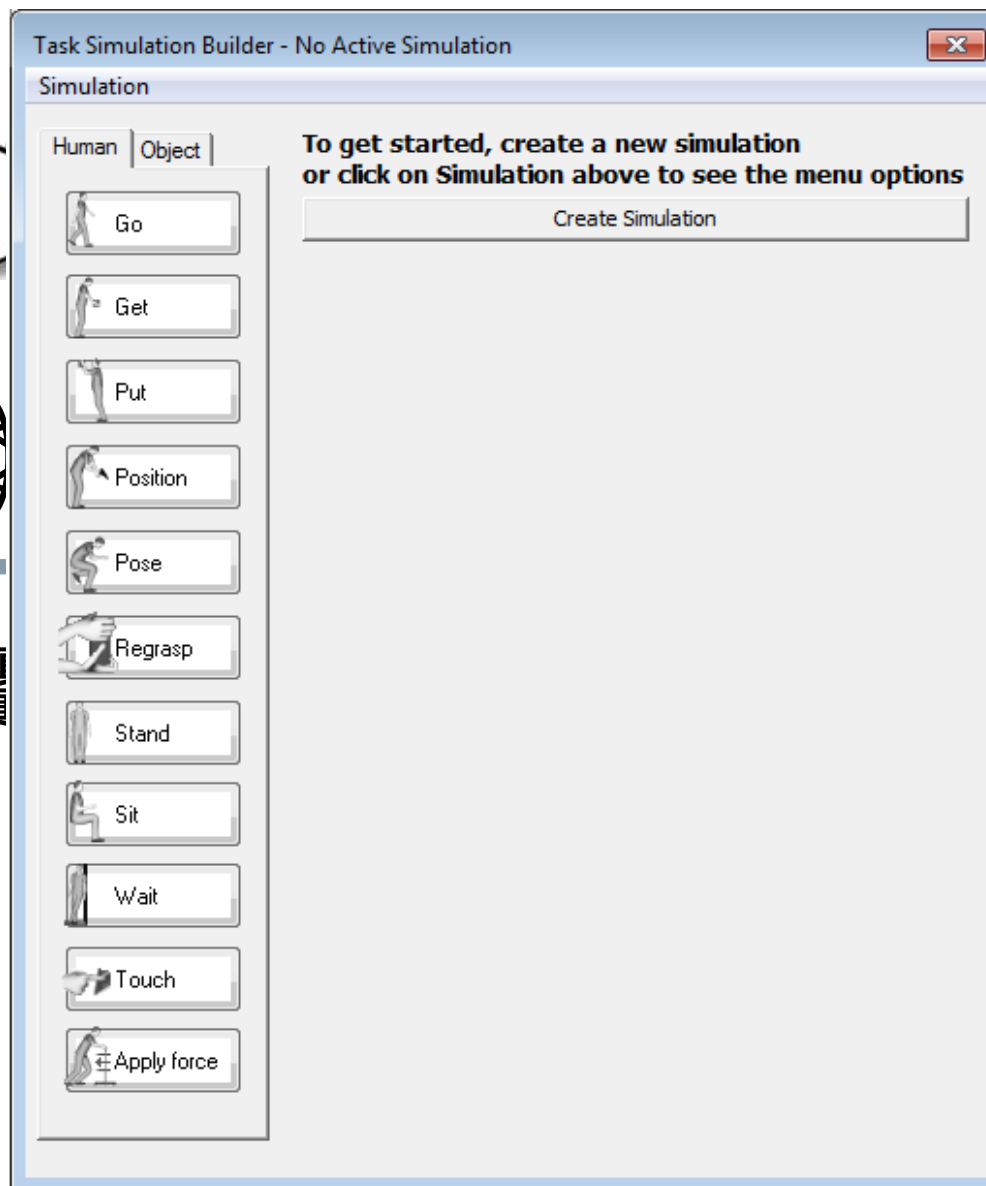




①

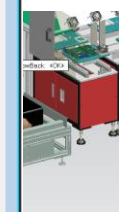


确定仿  
及仿真

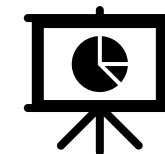


②

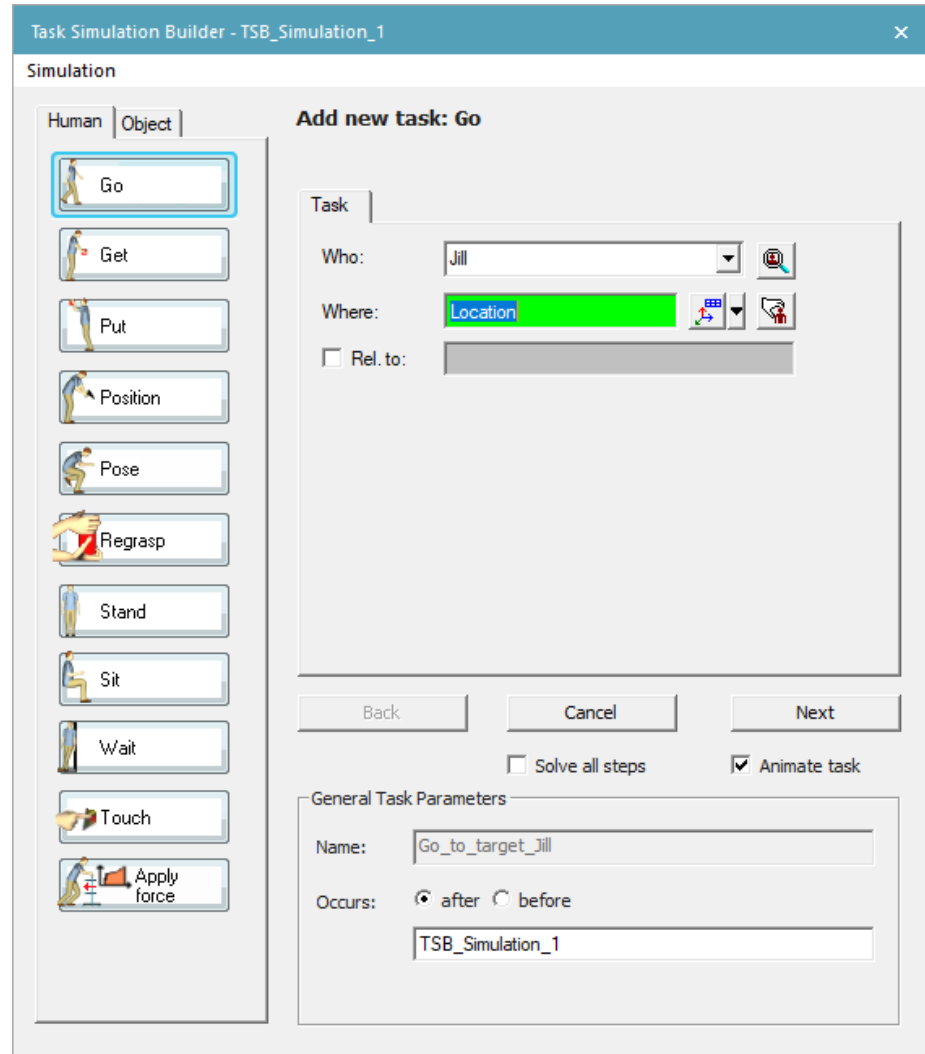
建模



⑤

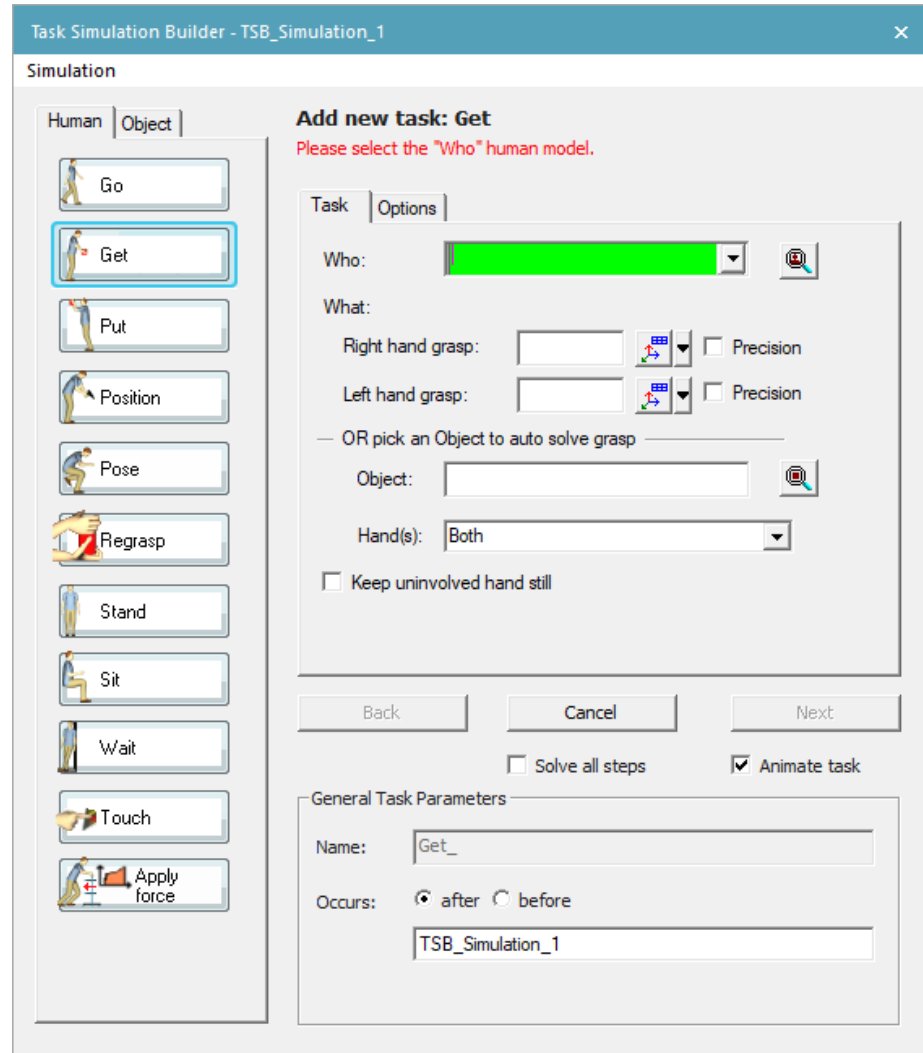


人因工程分析

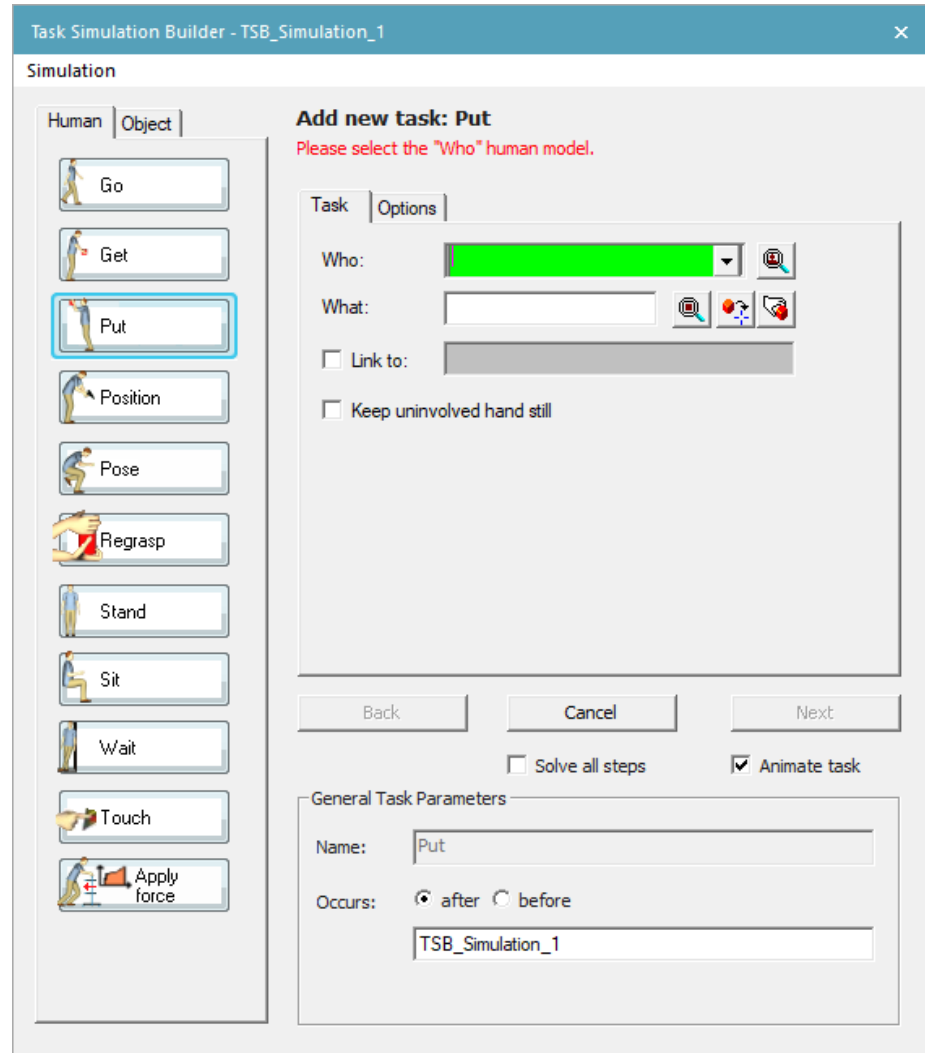


You can select any ghost model and modify its position or delete it.

You can configure the Task Simulation Builder to consider selected objects to be obstacles and to be avoided when planning human model motion. For example, if you set a table to be an obstacle, you will not have to implement a via point to prevent the human model from walking through the table. For more information, refer to Manage walk obstacles

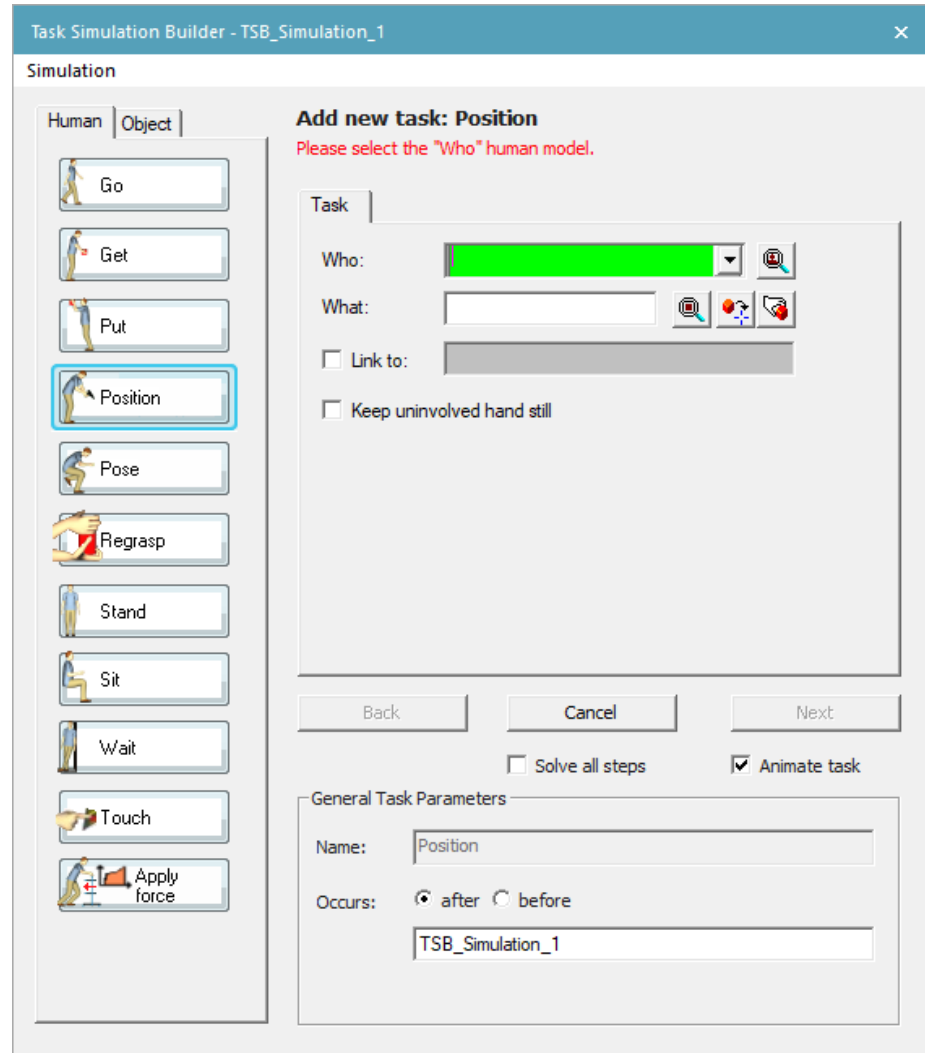


You can use the **Get** task to have the model pick up or grasp an object within the scene. You can define which hand(s) to use or let the Task Simulation Builder solve it for you. You can also choose to override the solved destination, if the human model needs to walk to the object, and specify exactly where it should stand. You can also use **Via Postures** to specify the exact path for the model to follow when reaching for the object. This is especially useful if you wish to define a collision-free path for the human model.

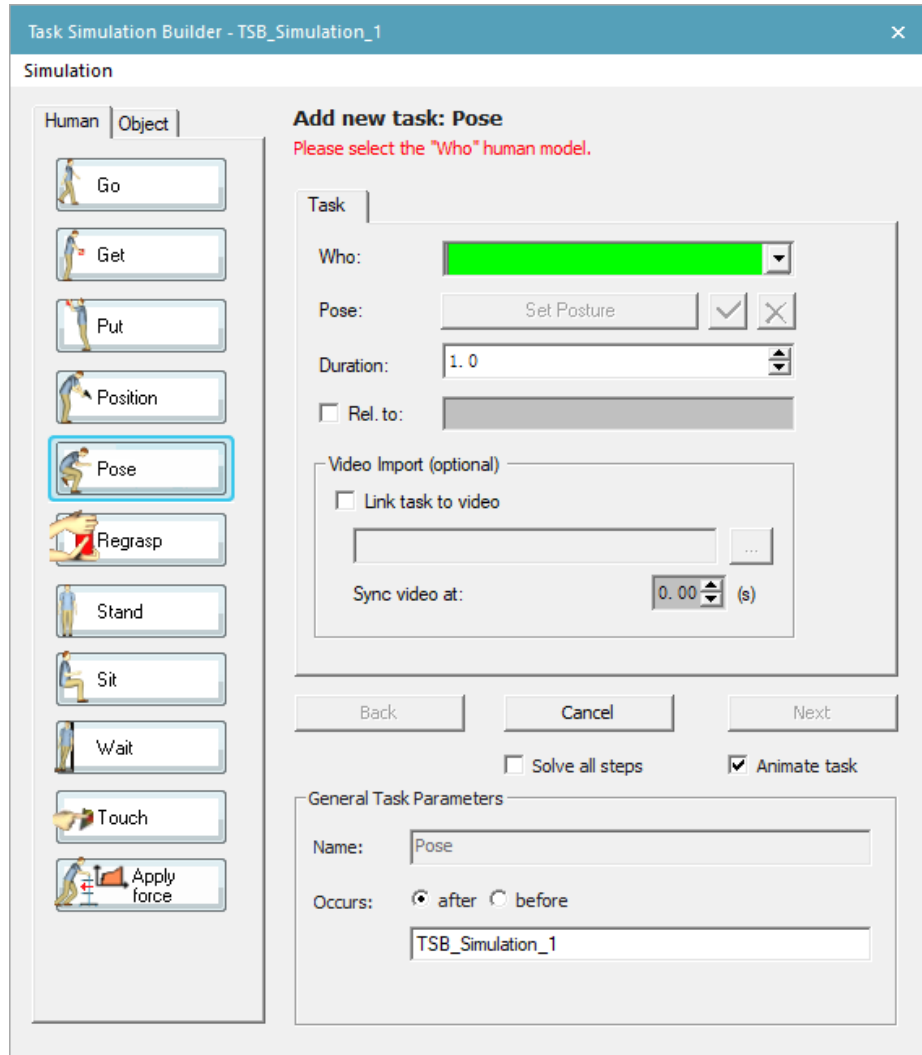


The **Put** task enables you to move a grasped object to a new location. For example, if the human model picked up a tool, you can use the Put task to take it to a workstation. Task Simulation Builder can solve all the actions for the Put, or you can choose to define a specific walk path as well as preferred postures to Put the object.





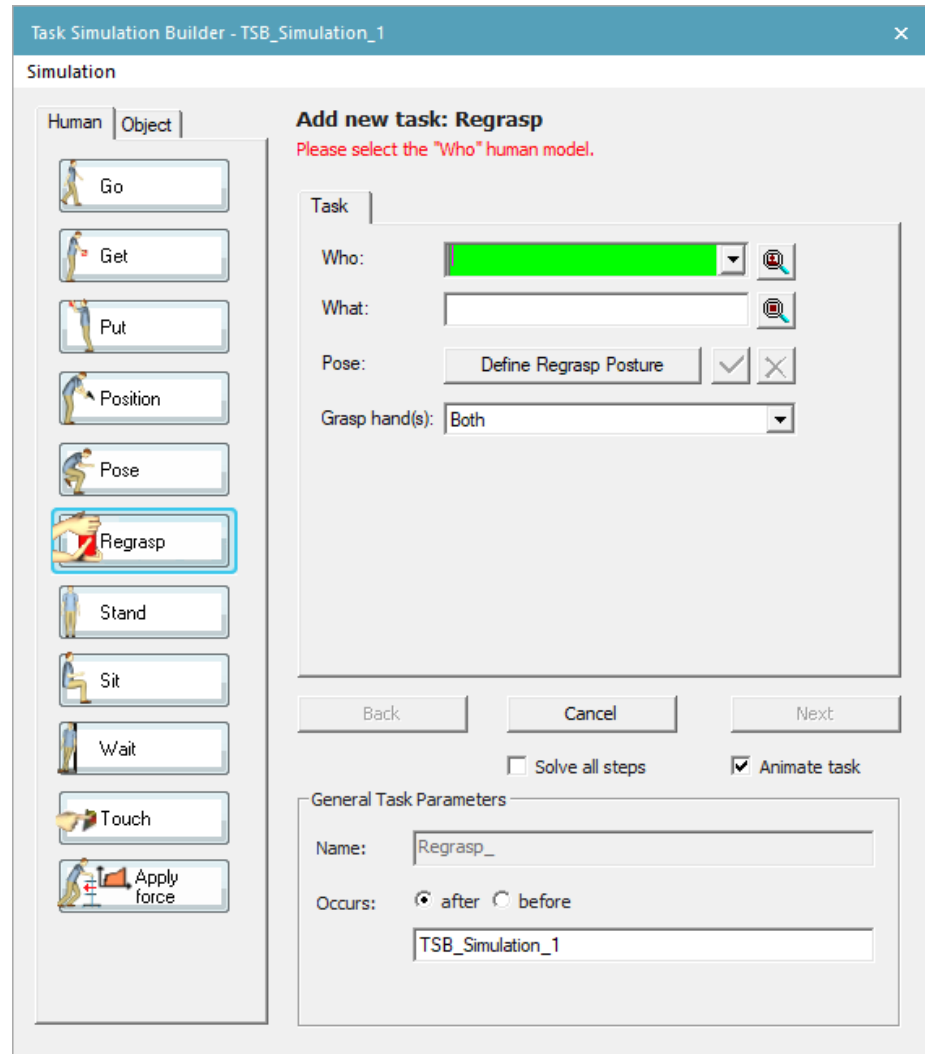
**Position** tasks are similar to **Put** tasks - the difference is that the human continues to hold the object at the end of a Position task. This is useful, for example, when using a power tool to fasten a part. You can position the tool at the first fastener location, and at subsequent locations. The human continues to hold the power tool at each Position task.



Pose task  
model in  
the task.  
you can  
sequenc  
are not e  
Builder t  
to show  
standing  
If you ha  
can also  
of motion  
**Record**  
link then  
video pla  
review, s  
sequenc



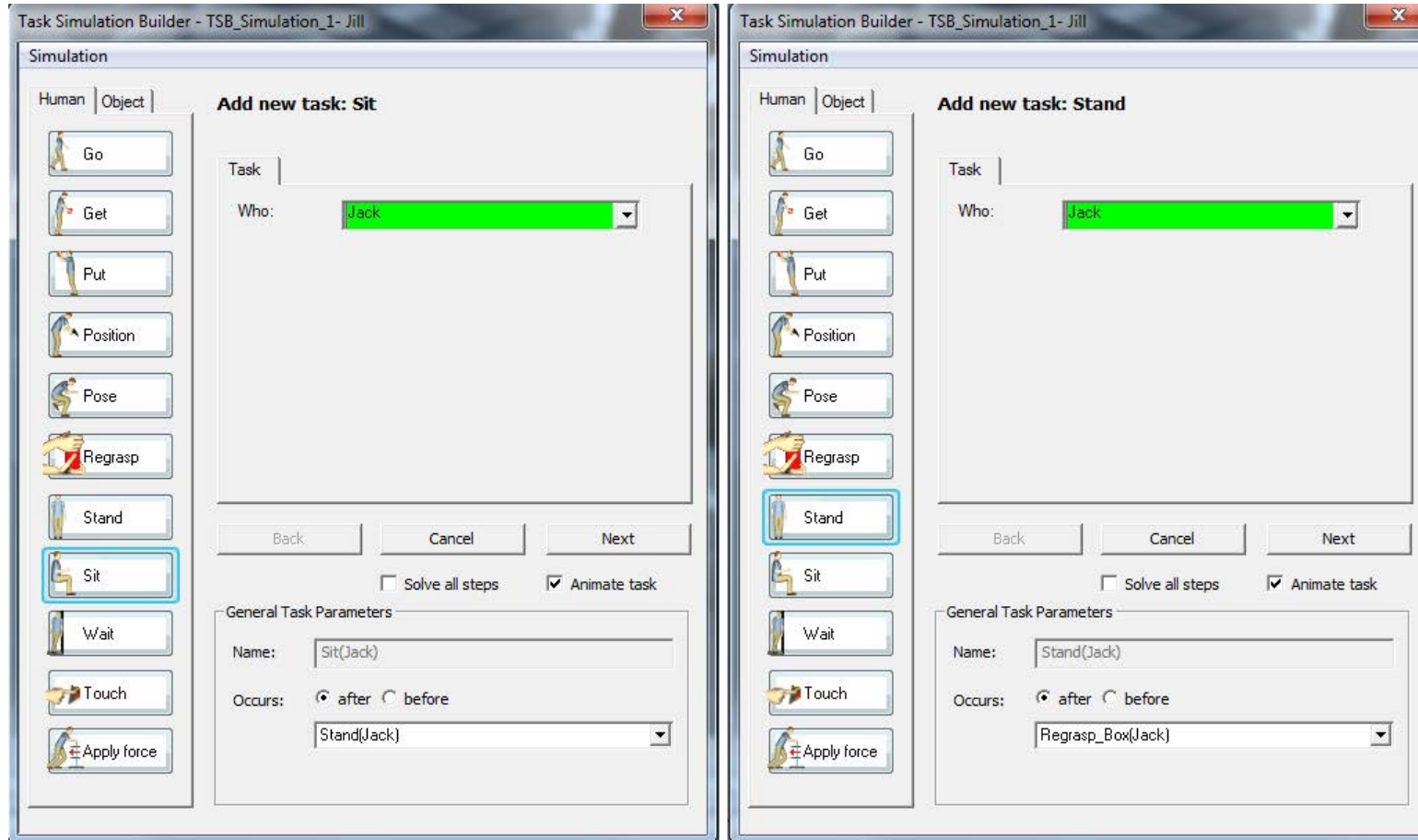
re the human  
ne-frame for  
posture, or  
motion  
activities that  
Simulation  
e Pose tasks  
g to a  
toolkit, you  
nced editing  
use **Posture**  
quire and then  
With the  
ou can then  
in the



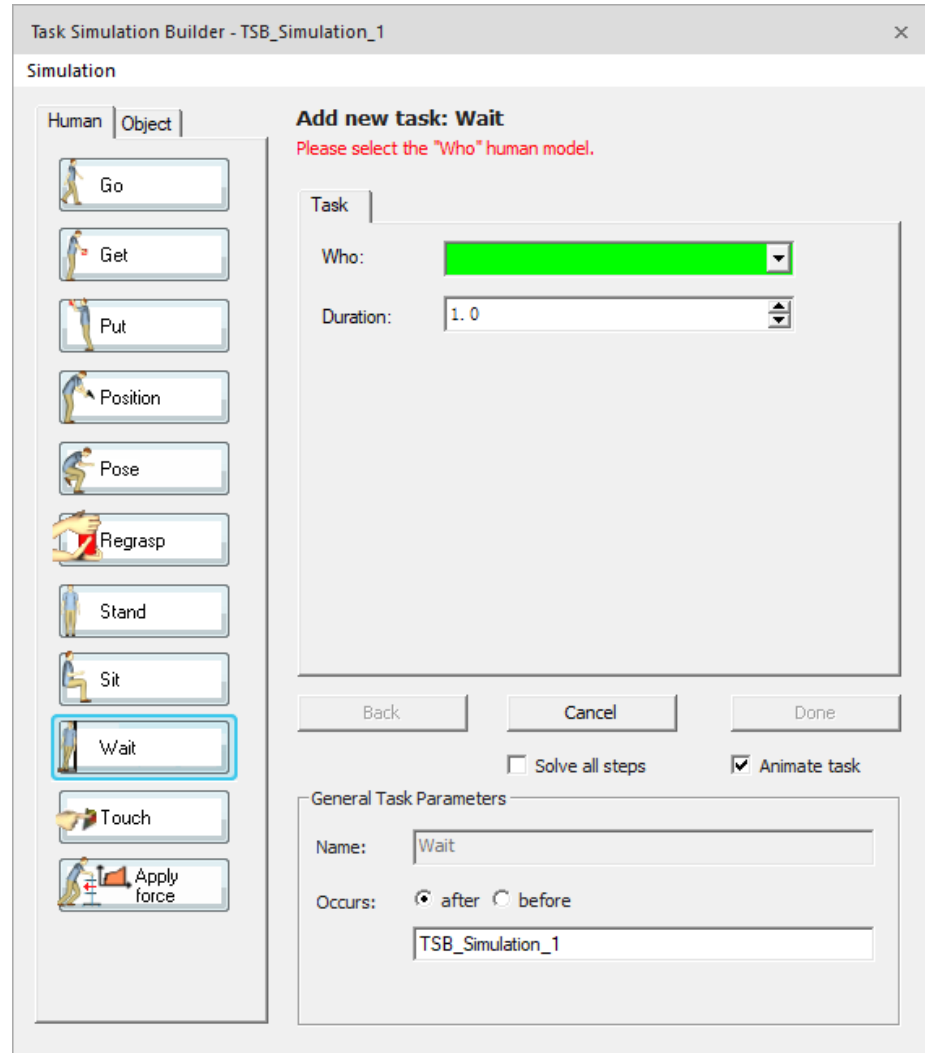
The Regrasp task enables updating the human's grasp of an object at any point within the simulation. This task lets you change which hand(s) grasp an object. You can also change the location/orientation of the object as well as the grasp or posture of the human.

### Note:

The duration for a Regrasp task is very brief. If you wish to show a motion (with a specific duration), it is recommended to insert a Position or Pose task prior to regrasping. For example, if the human model needs to bend or stand up and then regrasp, first move the human model to the necessary position and then add a Regrasp task.

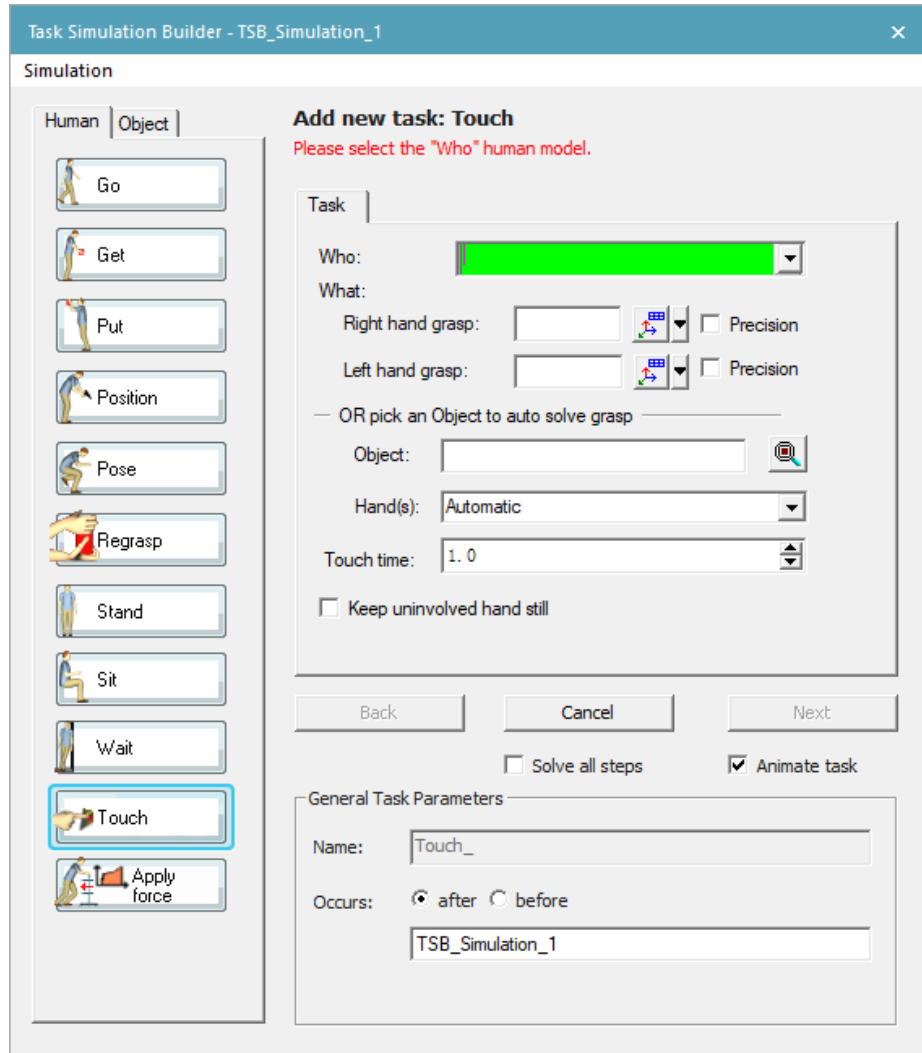


At any point during a simulation, you can switch the position of the human model from sitting to standing and vice versa. This task does not include any type of motion for the model, it simply changes the 'state' so that all tasks added after switching recognize the new state (sitting or standing). In order to simulate the motion of sitting or standing, you can use the Pose task.

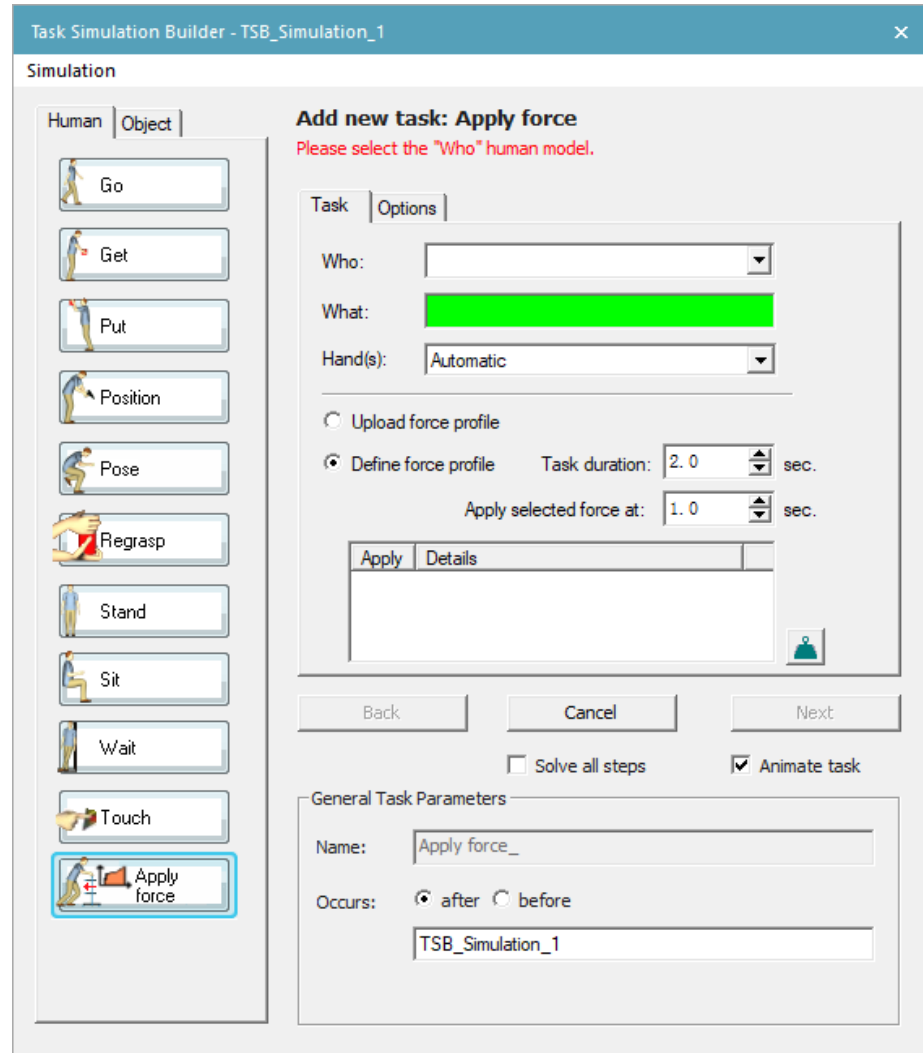


The Wait task lets you insert waiting time in your simulation time-line to account for pauses. For example, after walking to the conveyor, the human needs to wait for the part to arrive. This does not cause any change in the previously defined task.

Using **Touch** tasks you can select an object that the human model needs to touch, for example, to press a button to activate a conveyor. A Touch activity may include a walk to get to the final Touch destination. You can define the final posture and insert via postures to specify a path to implement the Touch activity.







Using the **Apply force** task, you can transfer the force (and weight) associated with an object to a human model. The human posture updates according to the forces applied during the task, reflecting the level of exertion. The human model transitions smoothly in and out of these exertion postures. Forces applied during these tasks are reflected in the ergonomic reports generated using the Task Simulation Builder. You can add and edit forces (define them as reaction forces) using the **Load and Weights** command ([Configuring loads and weights for a human event](#)).



施加于工人身体的静态/动态负荷主要影响肌肉骨骼系统

- 人体姿态分析

## Rapid Upper Limb Assessment (RULA)

- 快速上肢评估

## Timing Report

- 时间分析报告

## Force Solver

- 受力分析

## Arm Strength Evaluation

- 臂力评估

## Lower Back Analysis

- 下背部载荷分析



## Static Strength Prediction

- 静态强度预测

## NIOSH

- 搬运受力分析

## Metabolic Energy Expenditure

- 能量代谢分析

## Fatigue and Recovery

- 疲劳恢复分析

大部分工具主要依据National Institute for Occupational Safety and Health(美国职业安全与健康协会, 简称NIOSH)发布的人工操作实际指导而开发的分析系统。

\*NIOSH是一个联邦机构, 隶属于CDC(美国卫生与人事部的疾病控制与预防中心), 对各类的安全和健康问题进行研究。NIOSH为OSHA(美国职业安全与健康)标准提供技术上的协助, 推荐标准给OSHA进行科学研究并提出建议, 以预防职业病及工伤。

# 1) Lower Load Analysis (下背部载荷分析)

分析范围		
注释	动态	静态
✓	✓	✓

**SIEMENS**  
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下背部载荷分析可以分析特定操作下脊椎受力对下背部的影响是否符合NIOSH的标准，是否会令工人下背部的受伤概率增加。分析可以给出哪些任务最需要进行人因方面改进，从而对工厂车间的布局规划和工序进行安排来减小员工下背部受损的风险。

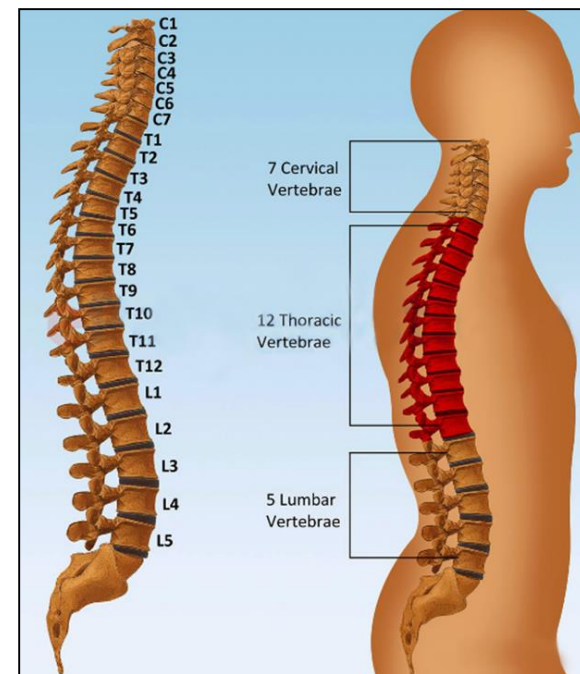
腰椎L4和L5关节为下背部主要承力关节，下背部载荷分析的针对对象就是L4/L5关节。

## 分析结论包括：

- (1) L4/L5 脊椎处的压力，并将其与NIOSH推荐受力和极限受力对比；
- (2) 上半身重力及提举物体的重力对 L4/L5 脊椎范围处各个关节产生的扭矩；
- (3) 背部主要肌肉在承载压力下产生的肌肉张力；

减少背部压力的常用方法包括：

1. 减轻负荷的重量。
2. 改变工作环境，使工人不需要弯腰去抬重物(避免弯腰)。
3. 确保负载较小、可以尽量靠近机身。
4. 避免不对称(扭曲)姿势。



错误姿势



正确姿势：蹲下去，拿稳，再起身



# 1) Lower Load (下背部载荷分析)

## 静态报告解读 (当前姿态的即时分析)

Analysis Recommendations:

The low back compression force of 4227.4 N

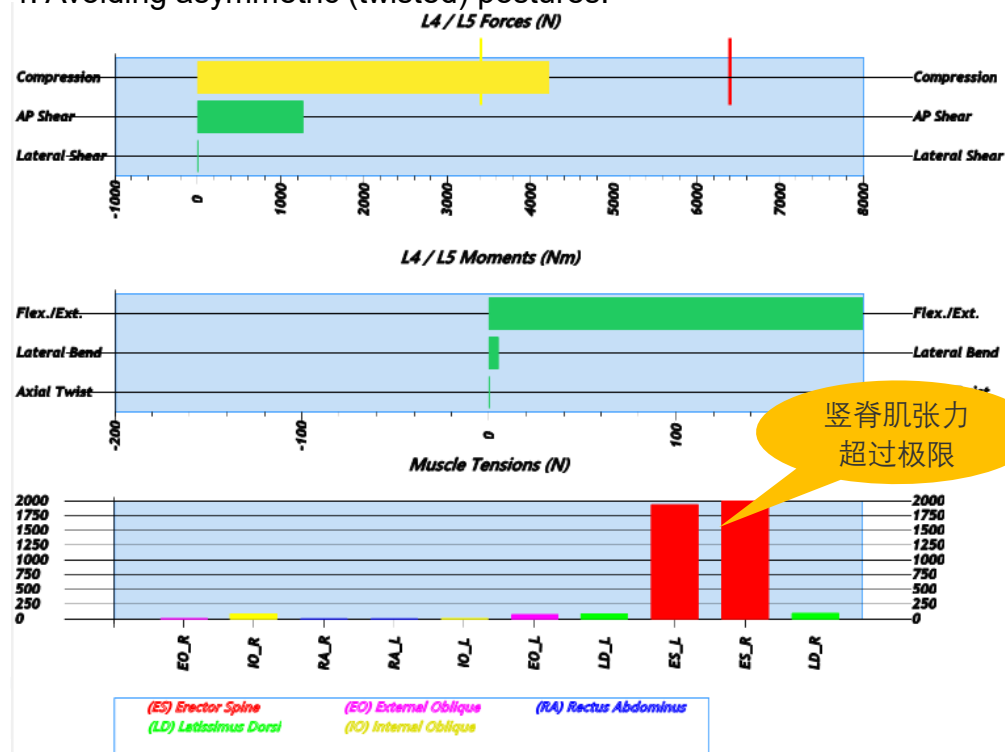
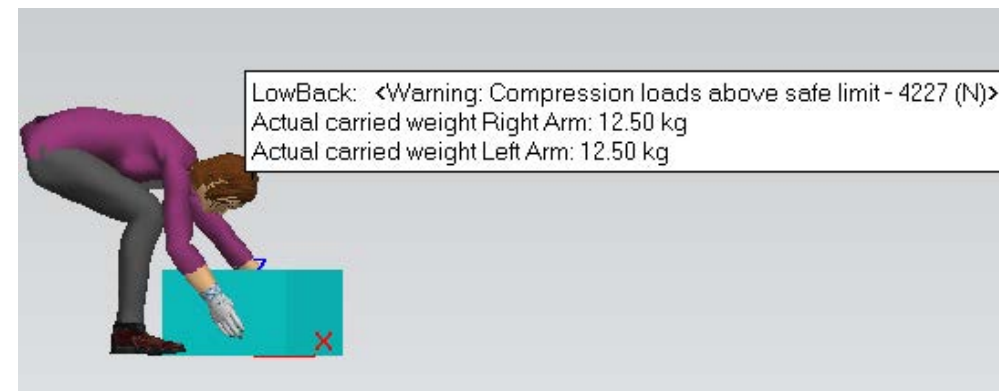
is above the NIOSH Back Compression Action Limit of 3400 N.

This represents an increased risk of low back injury for some workers.

It is recommended that this job is analyzed further for ways to reduce low back forces.

Some ways of reducing the back compressive forces include:

1. Reducing the weight of the load.
2. Changing the job environment such that the worker does not need to stoop to lift the load (avoid having to bend over).
3. Ensuring the load is small such that it can be held close to the body.
4. Avoiding asymmetric (twisted) postures.



脊柱受力因为人体承载的外力而改变。

当脊柱的压力超过3400N,直方图会变成黄色---3400N 是[NIOSH]标准给出的 [BackCompression Action](背部压力)的推荐值, 超过这个值意味着该动作会增大少部分工人受伤的风险。

当超过6400N后, 直方图就会变成红色---6400N是[NIOSH]给出的背部压力的极限值, 超过这个值会使大部分的工人都面临受伤的危险。

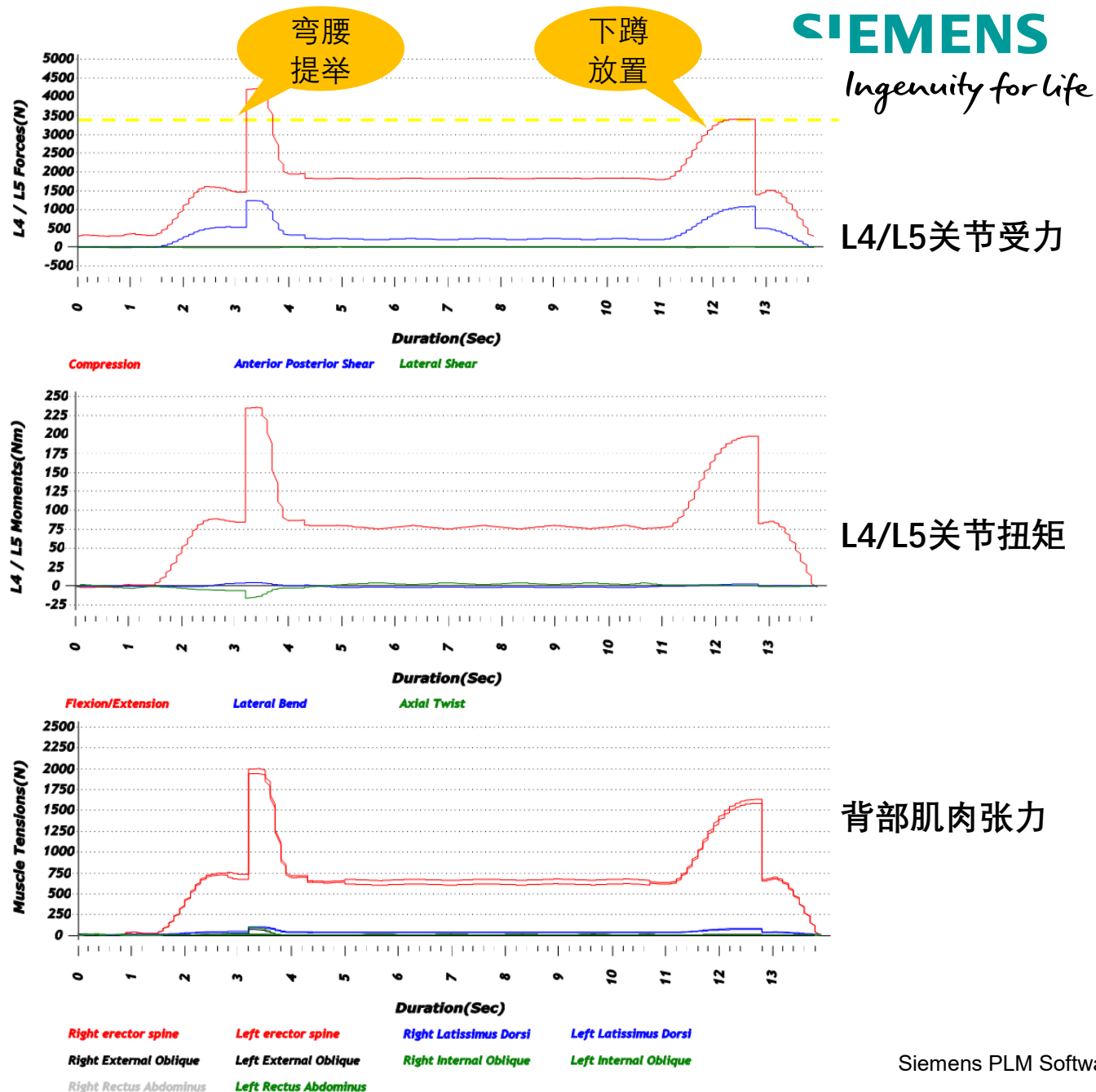
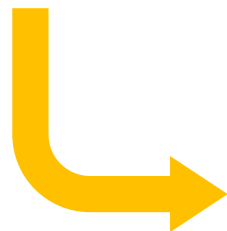
竖脊肌---顾名思义, 是能让脊椎骨竖立的肌肉, 它是人体最重要的肌肉之一, 由骶尾骨连接到头。人类区别动物能直立行走的原因, 就是有强有力的竖脊肌, 把整个脊椎竖起, 让上身直立, 支撑身体几十斤的重量。

在背部肌肉中, 最容易受到伤害的就是竖脊肌---很多时候竖脊肌的受伤往往会造成神经剧烈疼痛。临床统计发现, 多数腰痛、背痛, 臀部疼痛, 甚至严重的头痛头晕都是竖脊肌劳损引起的。

# 1) Lower Load (下背部载荷分析)

## 动态报告 (当前仿真全过程)

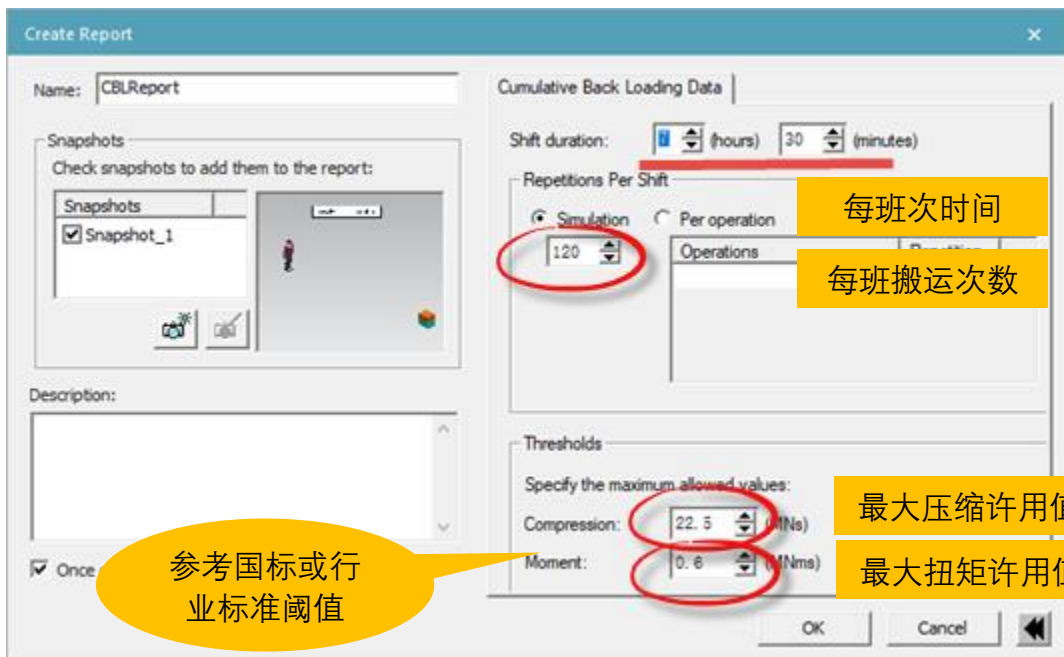
Data Filter		
L4 L5 Forces - All	<input checked="" type="checkbox"/>	
X	<input type="checkbox"/>	
Y	<input type="checkbox"/>	
Z	<input type="checkbox"/>	
L4 L5 Moments - All	<input checked="" type="checkbox"/>	
X	<input type="checkbox"/>	
Y	<input type="checkbox"/>	
Z	<input type="checkbox"/>	
Muscle Tension - All	<input type="checkbox"/>	
ES Right	<input checked="" type="checkbox"/>	
ES Left	<input checked="" type="checkbox"/>	
LD Right	<input checked="" type="checkbox"/>	
LD Left	<input checked="" type="checkbox"/>	
EO Right	<input checked="" type="checkbox"/>	
EO Left	<input type="checkbox"/>	
RA Right	<input checked="" type="checkbox"/>	
RA Left	<input type="checkbox"/>	
IO Right	<input checked="" type="checkbox"/>	
IO Left	<input type="checkbox"/>	





# 1.5) Cumulative Back Load (累积背部载荷)

分析范围		
注释	动态	静态
N/A	✓	N/A



Summary	
Shift Duration (Min)	450
Calculated Idle Time (Min)	385.3
Simulation Duration (Sec)	32.3
Total Cumulative Compression/ Shift (MNms)	14.6 (includes loading incurred during work tasks and idle time)
The low back cumulative compression exposure for this shift does not exceed the threshold of 22.5MNms.	
Total Cumulative Moment/ Shift: (MNms)	0.4 (includes moment incurred during work tasks and idle time)
The low back cumulative moment exposure for this shift does not exceed the threshold of 0.6MNms.	

Operation	Action	Duration (S)	Repetition / Shift	Compression (N)	Operation CL (Ns)	Operation CL / Shift (Nms)	Flex/Ext Moment (Nm)	Operation CM (Nms)	Operation CM / Shift (Nms)
Walk		1.45	120	304.53	441.6	52988.2	1.69	2.5	294.1
Get		1.75	120	1604.6	2801.6	336195.8	88.26	154.1	18492.2
Walk		6.74	120	1581.01	10521.2	1262544.9	66.18	446.1	53526.4
Put		2.94	120	3576.18	10503.2	1260388.9	200.71	589.5	70738.2
Pose		1	120	1527.16	1527.2	183259.2	85.76	85.8	10291.2
Walk		5.94	120	311.86	1851.8	222219	0.8	4.8	570
Get		2.87	120	1573.5	4508.1	540969.3	89.55	256.6	30787.3
Walk		5.9	120	1388.71	8193.4	983206.7	57.59	339.8	40773.7
Put		2.77	120	3231.68	8945.3	1073434.8	190.03	526	63120.4
Pose		1	120	1521.07	1521.1	182528.4	85.11	85.1	10213.2

↓ 外力情况不变、每班重复次数增加时，可见累积载荷增加并超过给定阈值

Summary	
Shift Duration (Min)	450
Calculated Idle Time (Min)	288.3
Simulation Duration (Sec)	32.3
Total Cumulative Compression/ Shift (MNms)	21.6 (includes loading incurred during work tasks and idle time)
The low back cumulative compression exposure for this shift does not exceed the threshold of 22.5MNms.	
Total Cumulative Moment/ Shift: (MNms)	0.8 (includes moment incurred during work tasks and idle time)
The low back cumulative moment exposure for this shift exceed the threshold of 0.6MNms, and may present an increased risk of injury.	

安大略大学背部疼痛研究 (OUBPS) 小组与General Motors Canada合作，发现了累积负荷暴露与报告腰痛的可能性之间的关系。累积负荷可以认为是在一天中经历的所有负荷的累积：

- 利用模拟操作来定义工作循环；
- 允许定义班次和每班重复次数；
- 提供最大曝光准则，同时允许用户自定义累积压缩和力矩阈值；
- 生成全面的摘要报告。

## 2) Static Strength Prediction (静态强度预测)

静态强度预测(SSP)人体工程学标准由密歇根大学工程学院/人体工程学中心开发。

SSP分析能够根据姿势、运动要求和人体对象来评估具有执行任务所需力量的人群比例。适合分析涉及提升/降低/推动/拉动的物料搬运任务,这种任务通常需要需要复杂的关节/躯干的扭曲和弯曲。

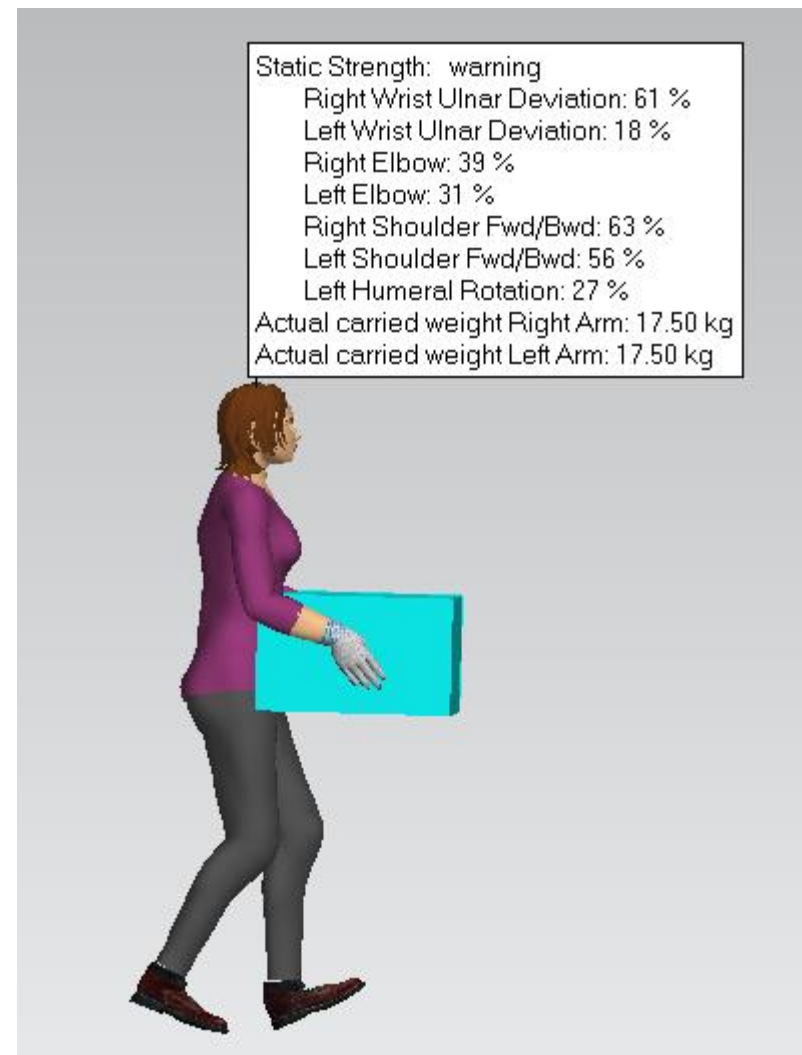
- 可预测具有执行规定任务所需力量的男性/女性的比例;
- 提供肘部/肩部/髋部/膝部各关节所需的角度, 以及屈曲/旋转和侧向弯曲所需的躯干角度;
- 提供躯干和四肢关节承载的扭矩以及受力情况。

\*与NIOSH工具的比较:

SSP未考虑加速度和动量, 因此最适合缓慢、沉重的物料处理运动。

分析范围		
注释	动态	静态
✓	✓	✓

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## 2) Static Strength Prediction (静态强度预测)

### 静态报告解读 (当前姿态的即时分析)

Create Report

Name: SSP\_Static

Filter By Percent Capable

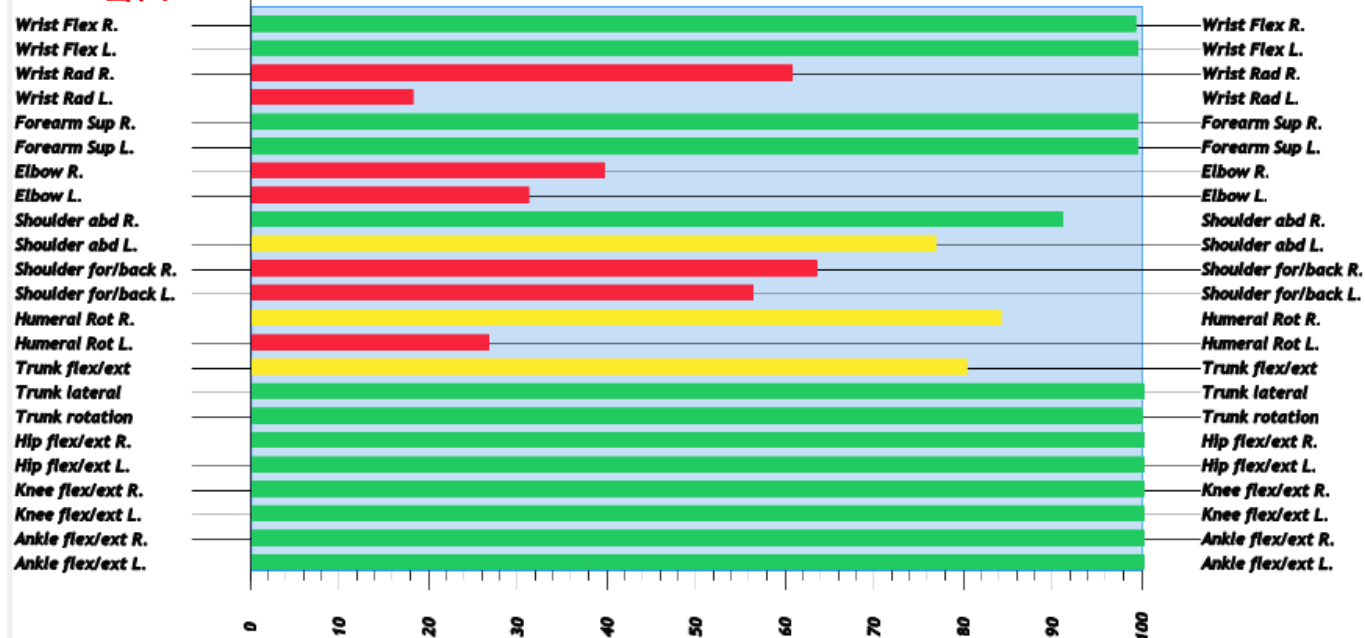
Gender	Threshold value(%)
Male Warning	99 %
Male Limit	99 %
Female Warning	90 %
Female Limit	75 %

设定阈值为99%的男性以及75%的女性不会受伤

Once created, open in the Report Viewer

关节/身体部位  
屈曲

Percent Capable (%) 可接受人群比例



## 2) Static Strength Prediction (静态强度预测)

### 动态报告解读

Create Report

Name: SSP\_Simulation 1

Filter By Percent Capable

Snapshots

Check snapshots to add them to the report:

Snapshots	
<input checked="" type="checkbox"/> Snapshot_1	

Description:

Once created, open in the Report Viewer

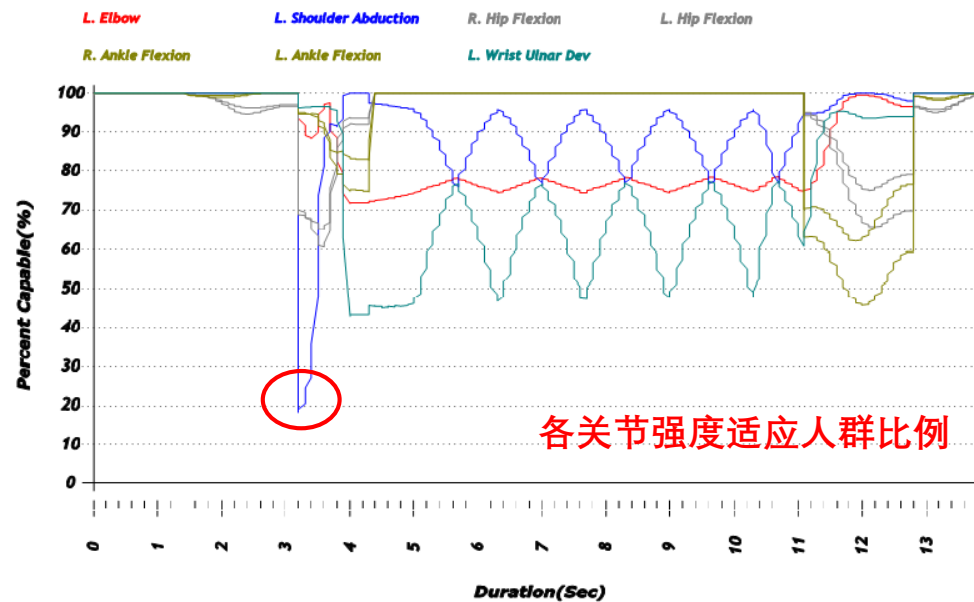
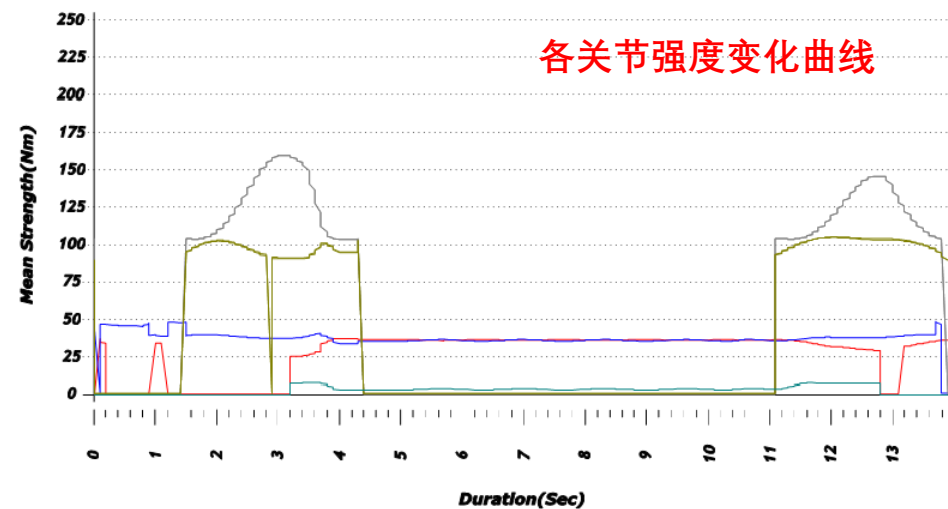
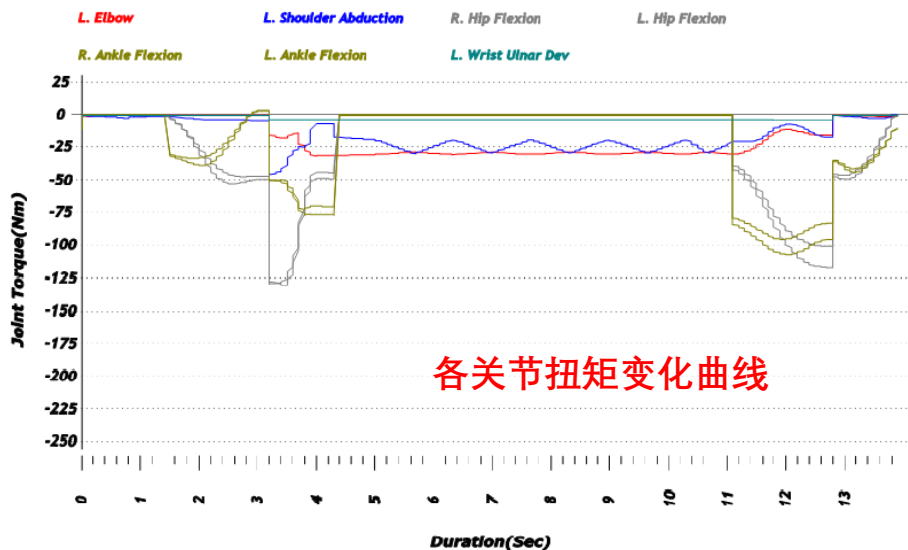
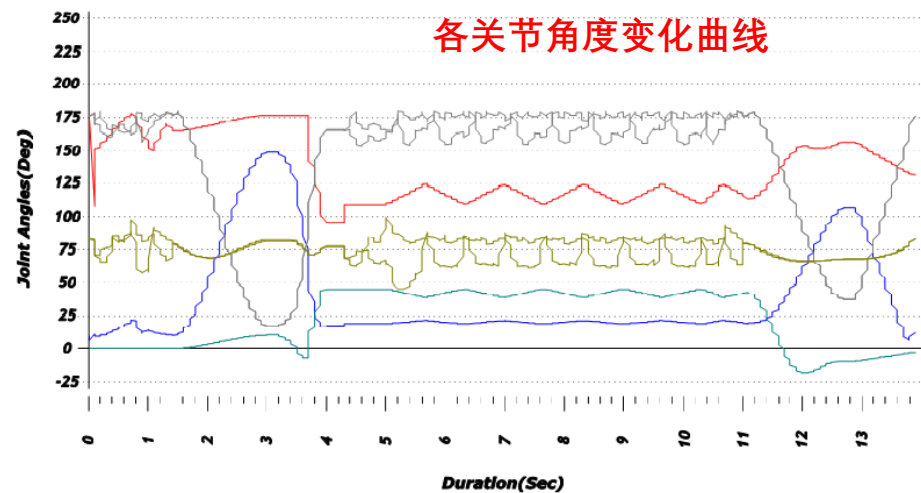
Body area	Threshold value(%)
Right Wrist Flex/Ext	75 %
Right Wrist Ulnar	75 %
Right Forearm Sup	75 %
Right Elbow	75 %
Right Shoulder Abduction	75 %
Right Shoulder fwd/bwd	75 %
Right Humeral Rotation	75 %
Right Hip Flexion	75 %
Right Knee Flexion	75 %
Right Ankle Flexion	75 %
Left Wrist Flex/Ext	75 %
Left Wrist Ulnar	75 %
Left Forearm Sup	75 %
Left Elbow	75 %
Left Shoulder Abduction	75 %
Left Shoulder fwd/bwd	75 %
Left Humeral Rotation	75 %
Left Hip Flexion	75 %
Left Knee Flexion	75 %
Left Ankle Flexion	75 %
Trunk Flexion	75 %
Trunk Lateral	75 %

OK Cancel

设定阈值为75%的人群不会受伤

## 2) Static Strength Prediction (静态强度预测)

### 动态报告解读





### 3) NIOSH (搬运受力分析)

分析范围		
注释	动态	静态
N/A	✓	N/A

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【NIOSH】(搬运受力分析)是主要依据美国国家安全与健康协会 1981 年发布的手工提升工作实际指导开发的分析程序,旨在分析员工双手搬起重物时的受力情况,得出一个搬运指数,然后与允许的搬运指数相比较,进而了解工人搬运过程的动作是否合理,以帮助避免或减轻员工背部损伤,其任务主要包括【lifting】(提举)、【lowering】(放下)、【pushing】(推)、【pulling】(拉)、【holding】(拿)、【carrying】(运)。1991 年【NIOSH】修订了【RWL】(搬举建议值)计算公式,即

$$RWL = 23\text{kg}(25/H)(1 - 0.003|V - 75|) \times (0.82 + 4.5/D)FM(1 - 0.0032A)CM \quad (15-1)$$

式中

$H$ ——搬举起始或终止时手掌中心距两踝关节中间的水平距离 (cm);

$V$ ——搬举起始或终止时手掌距地面的垂直距离 (cm);

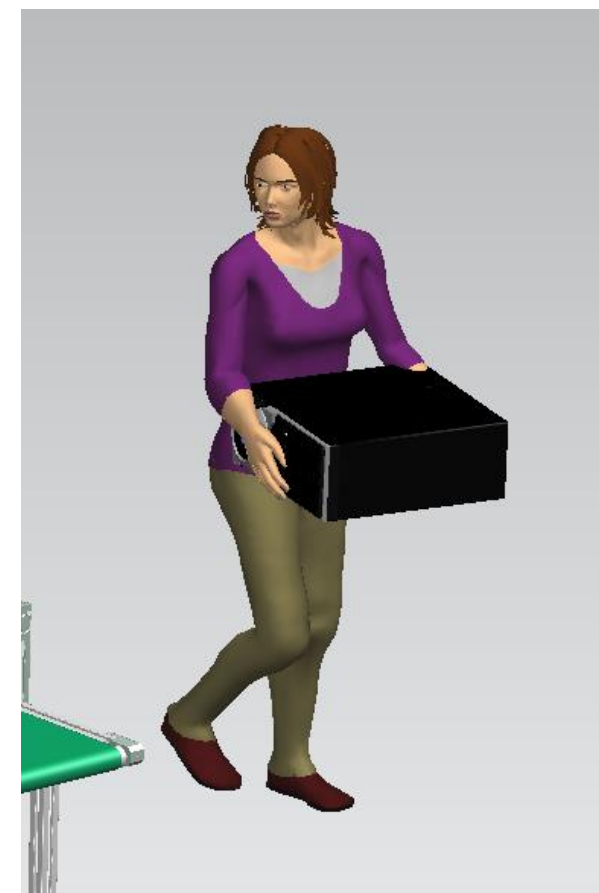
$D$ ——搬动起始与终止时的垂直距离 (cm);

$FM$ ——搬动频率参数 (根据频率确定不同的系数);

$A$ ——偏离矢状面的角度 (度);

$CM$ ——物体易抓参数 (根据难易确定为 1.0, 0.95, 0.90)。

根据不同的工作状态可计算【LI】(提举指数)。LI=实际提举重量/RWL。如果【LI】(提举指数)大于 1.0,提示当前工作状态可能构成对作业人群的危害。如果【LI】(提举指数)大于 3.0,则危害明显增加。在【RWL】(搬举建议值)基础上,【NIOSH】分别提出了单项任务的【LI】(提举指数)和复合任务的【CLI】(综合提举指数),并有效指导工作设计。





### 3) NIOSH (搬运受力分析)

#### 约束及改善措施

#### 输入信息

NIOSH工具假设评估的搬运任务满足以下条件:

- (1)活动不需要大量的能量消耗。
- (2)没有意外滑倒, 跌落或其他创伤事件。
- (3)任务不涉及单手起重或坐着提升。

搬运受力改善措施包括重物重量、手离开身体的距离、双手距离地板的垂直高度、躯干弯曲的程度、手和物体配合的程度以及起重的频率和持续时间。

\*NIOSH分析主要评估工人在双手提升任务开始和结束时的姿势, 两者之间的行走过程未纳入考虑 (如涉及到爬升台阶除外)。

\*在NIOSH 81基础上优化的是, NIOSH 91可以计算不对称姿势对提升动作的影响, 并支持多任务分析, 可以对多个动作执行计算而生成复合升力指数 (CLI)。

NIOSH Details - TSB\_Simulation\_1 - Jill

Shift duration:  <= 1 hours  <= 2 hours  每班次时长

Frequency (Lifts/Min)

Apply to all tasks in simulation  
5.0 每班重复次数

Enter frequency and coupling per task.

Operation	Frequency	Coupling
Get_PartPrototype_Jack	1.0	Good
Get_PartPrototype_Jill	1.0	Good

OK Cancel

# 3) NIOSH (搬运受力分析)



## 报告解读

### Summary of NIOSH 91/81

Lift No.	Operation	Object Weight (kg)	Frequency (Lifts/Min)	Origin Destination	NIOSH91		NIOSH81
					RWL (kg)	LI	AL (kg)
1	Get_PartPrototype_Jack_Grasp Put_PartPrototype_Jack_Release	25	1	Origin Destination	7.39 7.79	3.38 3.21	9.13 9.13

### Lift 1 of 1 Get\_PartPrototype\_Jack\_Grasp Put\_PartPrototype\_Jack\_Release Measure and record task variables

Object Weight (kg)		Hand locations (mm)				Vertical Distance (mm)	Asym.Angle (deg)		Frequency lifts/min	Duration Rate (HRS)	Object Coupling
L(Avg)	L(Max)	Origin		Dest		D	Origin	Dest	F	-	C
25	25	H	V	H	V	3.8	A	A	1	8	Good
435.9	72.8	442.1	76.6				18	3			

#### NIOSH91 Details

Multipliers and Recommended Weight Limits (RWL)

ORIGIN	RWL	=	LC	*	HM	*	VM	*	DM	*	AM	*	FM	*	CM	=	7.39	kg
DESTINATION	RWL	=	23	*	0.57	*	0.8	*	1	*	0.94	*	0.75	*	1	=	7.79	kg

Lifting Index (LI)

ORIGIN	Lifting Index	=	Object Weight (L)	/	RWL	=	25	/	7.39	=	3.38
DESTINATION	Lifting Index	=	Object Weight (L)	/	RWL	=	25	/	7.79	=	3.21

#### NIOSH81 Details

Multipliers and Action Limits (AL)

ORIGIN	AL	=	LC	*	HM	*	VM	*	DM	*	FM	=	9.13	kg
DESTINATION	AL	=	40	*	0.34	*	0.73	*	1	*	0.92	=	9.13	kg

Maximum Permissible Limits (MPL)

ORIGIN	MPL	=	3	*	AL	=	3	*	9.13	=	27.4	kg
DESTINATION	MPL	=	3	*	AL	=	3	*	9.13	=	27.4	kg

分析完毕，NIOSH81会给出以下两项参考指标:

- 1)重量建议(Action Limit---AL):从统计的角度来说，75%的女性以及99%的男性工人能够承受。
- 2)最大允许极限(Maximum Permissible Limit---MPL):仅有1%的女性和25%的男性工人可以承受。

NIOSH91包括下面两项指标:

- 1)推荐承受值(Recommended Weight Limit---RWL):几乎所有健康工人在特定条件下可以在相当长的时间内提升的负荷。
- 2)抓举指数(Lifting Index---LI):即当前负载与RWL的比值，它能够近似地评估人体疲劳,当LI>1时，表明此作业过程发生危险的程度增加，从长远的利益看，需要做出一些改进，[LI]数值越大，腰背疼痛的风险越高。

## 4) Metabolic Energy Expenditure (能量代谢分析)

### 概述

新陈代谢分析工具可以对工人生理及任务情况进行描述，对现有的工作或新工作的新陈代谢能量消耗进行分析，明确是否超过【NIOSH】的限定值，以及是否会使得疲劳损伤的风险提高。通过分析可以得出对能量消耗影响最显著的因素，并且预测出哪些改变可以使工作的能量消耗减到最小。

### 计算方法

【Metabolic Energy Expenditure】(新陈代谢分析)旨在计算人的体力消耗，用于判断一个工人持续不断工作时的劳动强度，评估其新陈代谢能耗，看劳动强度是否过大。人体总代谢能量包括动作代谢能量和姿势代谢能量。其中，动作代谢能量的计算必须获得仿真过程中与该人体对应的各项动作参数，包括【Lowest Position】(最低位置)，【Highest Position】(最高位置)，【Human Weight】(体重)，【Gender】(性别)，【Load】(负重)，【Force】(受力)，【Slope】(斜度)，【Time】(时间)，【Walk Speed】(行走速度)，【Distance】(距离)，【Category】(动作类型)，【Detail】(具体类型)，【Frequency】(频率)。人体姿势能量消耗计算公式为：

$$E_{\text{posture}} = K_{\text{posture}} \cdot \text{Weight} \cdot T_{\text{posture}}$$

### 改进措施

降低能源消耗率的方法包括：

- 尽量减少整个身体的运动(举升、行走、攀爬等)。
- 减少被操控物品的重量。
- 减少起重活动的次数

Metabolic Energy Expenditure

Human Data  
Human: Jill  
Gender:  Male  Female  
Weight: 63 (kg)

Duration  
Cycle: 6 (min)  
Work time: <1hrs  
Arm work: 50 (%)  
Body work: 50 (%)

Posture  
Standing: 100 (%)  
Sitting: 0 (%)  
Bent: 0 (%)  
Total: 100 (%)

Task Data  
Description: to destination  
Category: Walks  
Detail: Inclined  
Time: 10.00 (sec)  
Slope: 0 (%)  
Distance: 50 (m)  
Frequency: 1  
Update Add

Task List

Description	Category	Details	Energy	Frequency	Low
walk	Walks	Inclined	0.354	1	--
squat	Carries	Arm length at side	0.026	1	--
lift	Carries	Arm length at side	0.107	1	--
to destination	Walks	Inclined	6.948	1	--

Total task time: 0.30 (min)

Summary  
Total task energy: 7.437 (kcal)  
Energy expenditure rate: 1.926 (kcal/min)  
Standing posture energy: 4.120 (kcal)  
Sitting posture energy: 0.000 (kcal)  
Bent posture energy: 0.000 (kcal)

Create Report... Save As... Load... OK Cancel

## 4) Metabolic Energy Expenditure (能量代谢分析)

### 报告解读

Task Descriptions												
Description	Category	Details	Kcal	Frequency	Low position	High position	Load	Time	Force	Walks speed	Distance	Slope (%)
walk	Walks	Inclined	0.4	1	--	--	--	3	--	120	6	0
squat	Carries	Arm length at sides	0	1	--	--	0	2	--	0	0	0
lift	Carries	Arm length at sides	0.1	1	--	--	29	3	--	0	0	0
to destination	Walks	Inclined	6.9	1	--	--	29	10	--	300	50	0

报告计算出每个任务的新陈代谢能量消耗，以卡路里为单位。通过对每个任务能量相加得到总能量，总能量又分为**保持姿势消耗的能量**和执行任务消耗的能量，这些信息可以计算出每个工作执行周期消耗能量的频率。将新陈代谢能量消耗的分析结果和【NIOSH】给出的标准消耗和极限消耗进行对比。在超过标准消耗和极限消耗时会用特殊的颜色给出提醒，从而定义出工作中消耗最严重的任务。

Energy Expenditure Summary	
Cycle (min)	6
Total Task Energy (kcal)	7.4
Standing Posture Energy (kcal)	4.1
Sitting Posture Energy (kcal)	0
Bent Posture Energy (kcal)	0
Total Energy Expenditure (kcal)	11.6
Energy Expenditure Rate (kcal/min)	1.9

The estimated energy expenditure rate for this job (1.9 kcal/min) is below the recommended value of 4.1 kcal/min, indicating a nominal risk of muscle fatigue for most healthy workers.  
“这项工作的估计能量消耗率(1.9千卡/分钟)低于4.1千卡/分钟的建议值，表明对大多数健康工人来说不存在肌肉疲劳的实际风险”

\*本工具并不对工人的性别、年龄、身体状况、心理状况，以及任务中对新陈代谢能量消耗影响很小的环境因素（如温度等）进行分析，对于动作幅度非常小的任务也不进行分析。

## 5) Fatigue and Recovery (疲劳恢复分析)

分析范围		
注释	动态	静态
N/A	✓	N/A

### 概述

疲劳工具可以分析每个任务对肌肉导致的疲劳情况，以及恢复肌肉强度需要的休息时间，各个任务的休息时间相加就是整个工作的所需休息时间，通过与实际可用的休息时间对比，可以得出以下结论：

(1) 如果可用的休息时间超过所需的恢复时间，则认为该任务提供了足够的恢复时间以避免疲劳。**建议用户进行进一步的代谢研究以支持分析**

(2) 如果可用的休息时间小于所需的恢复时间，则假定该任务使工人面临疲劳风险，建议通过改变工人的载荷、工作频率或动作的姿态进行改进。

### 分析原理

疲劳的产生和消除都是人体正常的生理过程：人体一旦停止活动，即进入身体恢复过程。通过安排合理的休息时间即可恢复疲劳，因此工作时间和休息时间安排得是否合理，直接影响到工人的疲劳及工作能力。通过对员工某一姿势或一套连续动作导致的疲劳情况作分析，可以对工作的工序和设备进行改进，找出工作中最需要休息的时候，为员工制定疲劳度最小的工作。

### 约束条件

虽然工作时间和疲劳度是有很大的关联性(肌肉纤维类型、血液流动量、最大载荷、肌肉伸展度、肌肉温度、骨骼结构、骨骼环境、性别)，但是**本工具只分析了与肌肉强度之间的关联**，即只**考虑了由肌肉载荷引发的疲劳因素**；

本工具给出的对疲劳情况的分析结果应该作为降低工人疲劳风险的综合努力的一部分，为了能综合全面地分析出如何才能减少疲劳情况，需要与能量代谢分析、静态强度预测及下背部分析等工具共同使用。

**Caution:** 疲劳分析一定需要存在外力或重量载荷因素。



# 5) Fatigue and Recovery (疲劳恢复分析)

## 报告解读

Summary	
Simulation duration	32.3 sec
Recovery Time	For the current task demands recovery time is required for the following joints:
	Right hip: 0.5 sec
	Right knee: 0.2 sec
	Left ankle: 6.3 sec
	Right ankle: 17 sec
Potential Next Steps	Consider adding time to your overall cycle Consider modifying the task demands to reduce strain on the right ankle joint to start. Note that subsequent exertion reductions may be needed to avoid fatigue of other muscle groups as well.

对于目前的任务要求，需要以下关节恢复时间：

右髋关节:0.7秒

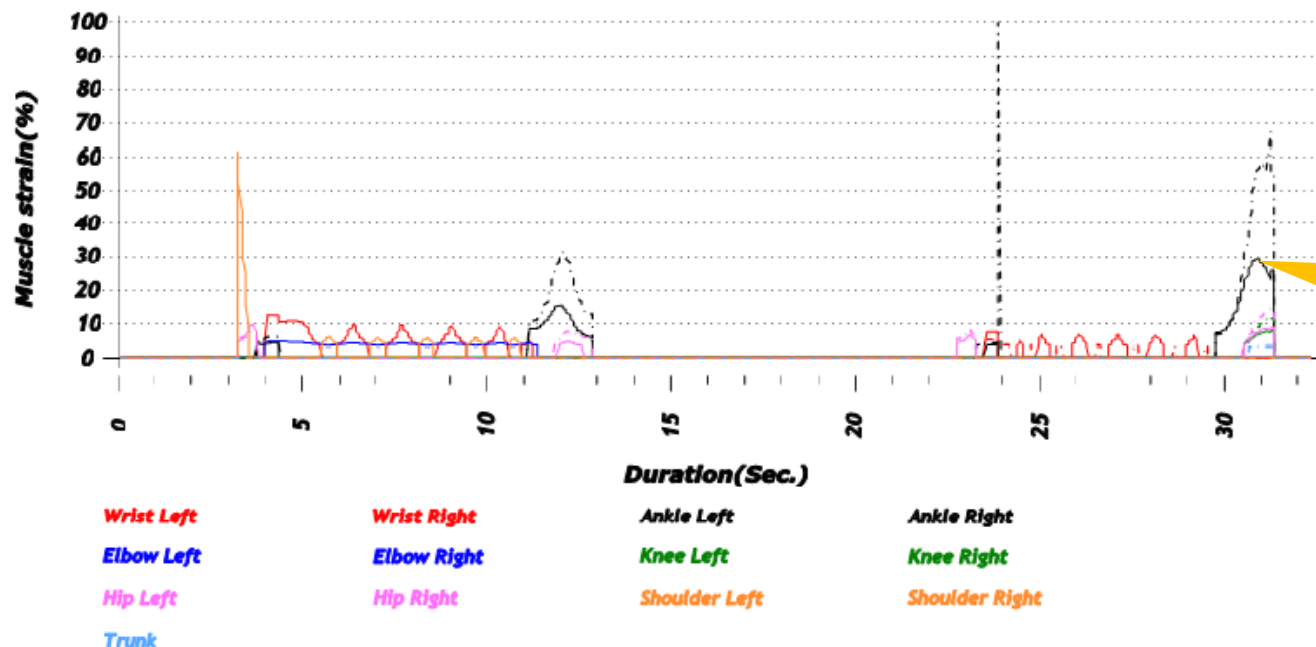
右膝盖:0.4秒

左脚踝:6.7秒

右脚踝:18.8秒

考虑增加你整个周期的时间。

考虑修改任务要求，以减少开始时对右踝关节的压力。注意，为了避免其他肌肉群的疲劳，可能还需要减少后续的运动。



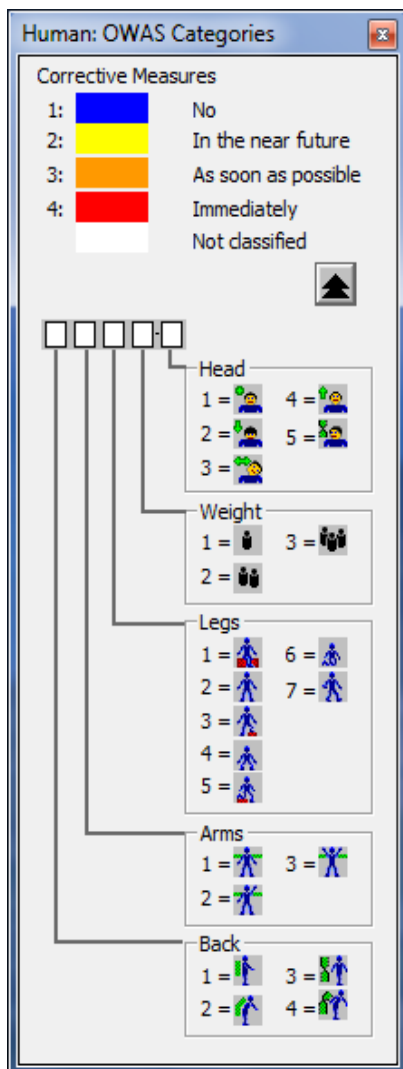
肌肉张力表示肌肉群的工作强度，如果达到最大值，则用百分比表示。这种肌肉张力被用作计算所需恢复时间的一部分。一般来说，肌肉群的张力值越高，需要的恢复时间就越长。



## 6) Working Posture Analysis (OWAS)

分析范围		
注释	动态	静态
✓	✓	✓

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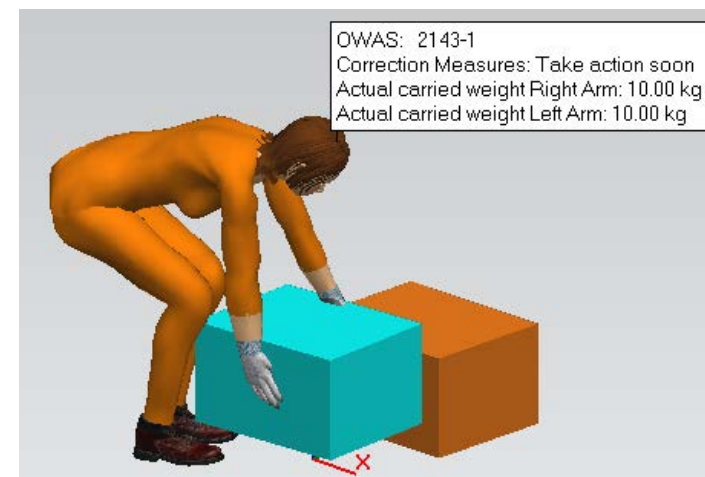


Ovako Working Posture Analysis (工作姿态分析) 简称OWAS, 是1977年至1981年在芬兰为钢铁工业开发的评价工具, 后由芬兰国家职业安全中心推荐。在日常工作空间设计分析中, OWAS 被认为是对各种工作场景的操作姿态进行人机分析的有效且容易实现的方法, 因而后来在工业领域得到广泛的应用。

OWAS可以快速检查工作姿态, 评价任务周期内所有工作姿态的舒适度, 并指示需要采取纠正措施的紧迫性, 从而快速评估某种工作姿态对工人造成损害或伤害的可能性大小, 可以确定最需优先改进的工作姿势, 以符合人体工程学的需要。

OWAS评分及工作姿势的“纠正需求”等级显示在一个对话框中, 四个等级如下:

疲劳等级	含义	采取措施
1	可以接受	姿势是正常的, 没有纠正的必要;
2	轻微伤害	姿势可能有一定的不良影响, 虽不需要立即采取行动, 但也应近期调整;
3	显著伤害	姿态有不良影响, 应尽快纠正;
4	严重伤害	姿势非常有害, 必须立即纠正。



# 6) Working Posture Analysis (OWAS)

## 报告解读

Time (Sec)	Operation	Object Weight (kg)	Category	Code Posture Combination						
				Back	Arms	Legs	Load	-	Head	
0	Get_PartPrototype_Jack_Walk	0	1	1	1	2	1	-	1	
0.03		0	1	1	1	7	1	-	1	
1.47	Get_PartPrototype_Jack_Bend_And_Reach	0	1	1	1	2	1	-	1	
1.7		0	2	2	1	2	1	-	1	
1.77		0	3	2	1	4	1	-	1	
2.43		0	4	4	1	4	1	-	1	
3.2	Put_PartPrototype_Jack_Arise_From_Bend	20	4	4	1	4	3	-	1	
3.5		20	3	2	1	4	3	-	1	
3.9		20	3	2	1	4	3	-	1	
3.97		20	1	1	1	2	3	-	1	
4.33		20	2	1	1	4	3	-	1	
4.37	Put_PartPrototype_Jack_Walk	20	1	1	1	7	3	-	1	
11.07		20	1	1	1	2	3	-	1	
11.37	Put_PartPrototype_Jack_Bend_And_Reach	20	3	2	1	2	3	-	1	
11.5		20	3	2	1	4	3	-	1	
12.83	Put_PartPrototype_Jack_Release	20	3	2	1	4	1	-	1	
13.73	Pose_Jack_Pose	0	2	2	1	2	1	-	1	
13.8		0	1	1	1	2	1	-	1	
15.07	Get_PartPrototype_Jill_Walk	0	1	1	1	7	1	-	1	
15.77		0	1	1	1	7	1	-	5	
15.9		0	1	1	1	7	1	-	1	
20.97	Get_PartPrototype_Jill_Bend_And_Reach	0	1	1	1	2	1	-	1	
21.23		0	2	2	1	2	1	-	1	
21.33		0	3	2	1	4	1	-	1	
22.7	Put_PartPrototype_Jill_Arise_From_Bend	18	3	2	1	4	2	-	1	
23.37		18	2	2	1	2	2	-	1	
23.47		18	1	1	1	2	2	-	1	
23.83	Put_PartPrototype_Jill_Walk	18	1	1	1	3	2	-	1	
23.87		18	1	1	1	7	2	-	1	
24.6		18	1	1	1	7	2	-	5	
24.73		18	1	1	1	7	2	-	1	
29.73	Put_PartPrototype_Jill_Bend_And_Reach	18	1	1	1	2	2	-	1	
30.07		18	2	2	1	2	2	-	1	
31.3	Put_PartPrototype_Jill_Release	18	2	2	1	2	1	-	1	
32.23	Pose_Jill_Pose	0	1	1	1	2	1	-	1	

各操作负荷情况

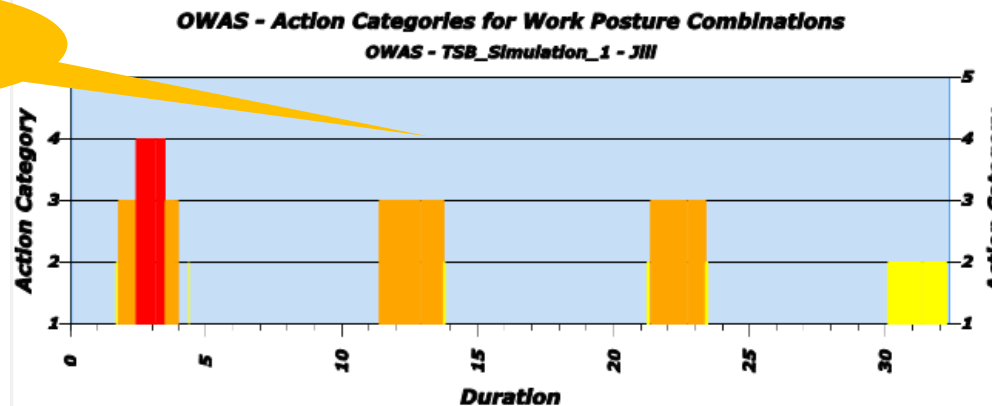
各操作的时间线

操作清单

各操作纠正紧迫性评价

各操作评分

各操作纠正评价变化柱状图



## 7) Rapid Upper Limb Assessment ( RULA)

分析范围		
注释	动态	静态
✓	N/A	✓



### 概述

快速上肢评估 (RULA) 方法由Lynn McAtamney博士和英国诺丁汉大学人体工程学家E.Nigel Corlett教授开发，是一种用于评估与工作相关的上肢疾病风险的姿势评估方法。

RULA可用于：

- 快速评估手动任务是否有可能使工人面临上肢受伤的风险。
- 设计新的手动任务或指导现有任务的重新设计。

### 评价方法

RULA系统检测下列风险因素:运动次数、肌肉受力情况、力量大小、工作姿势、持续的工作时间。

评估的主要部分：

A组：手臂和手腕分析

B组：颈部，躯干和腿部分析

所有因素加权后给出该姿态的最后评分(1~8分)，评分分为四等:

- 1)1~2分(1级操作)表明在没有保持或重复很长时间的条件下，该姿态是可行的(分析结果颜色为绿色)。
- 2)3~4分(2级操作)表明过较长时间后需要研究并改变该姿态(分析结果颜色变成黄色)。
- 3)5~6分(3级操作)表明隔一段时间就应研究并改变该姿态(分析结果颜色变橙红)。
- 4) 7分以上(4级操作)表明应立即对当前姿态进行研究并改变(分析结果颜色变深红)。

# 7) Rapid Upper Limb Assessment ( RULA)

## 报告解读

场景工况说明

Create Report

Name: RULA 3

Snapshots

Check snapshots to add them to the report:

Snapshots

Cell view

Vision view

Description:

Once created, open in the Report Viewer

Task Information

**Trunk**

Standing

Seated, well supported

Seated, without support

**Right Arm**

Shoulder is raised

Arm is supported or person is leaning

**Left Arm**

Shoulder is raised

Arm is supported or person is leaning

**Balance**

Legs and feet are supported and balanced (if not +2)

**Muscle Use**

None

Mainly static - held for more than 1 minute

Action occurs more than 4 times per minute

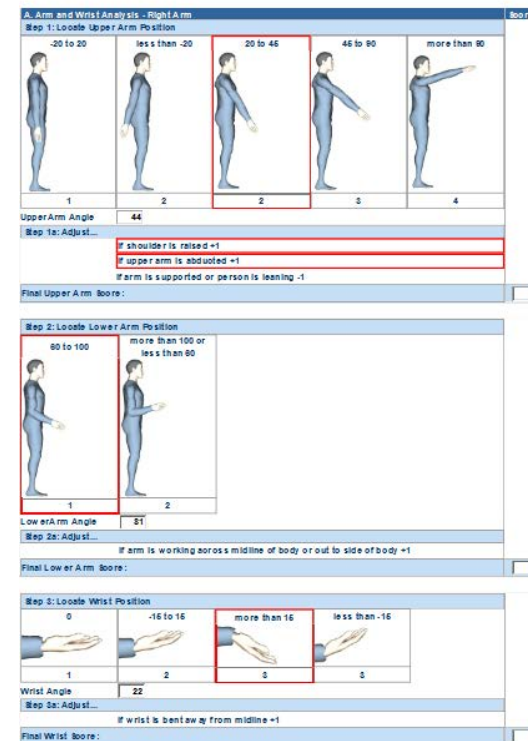
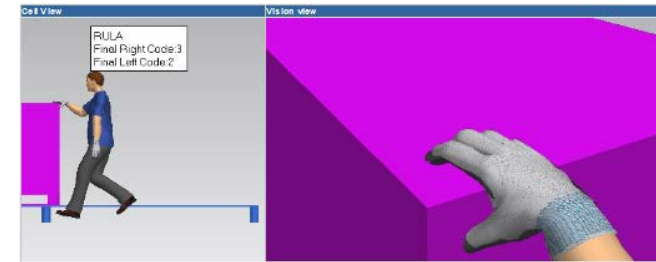
**Force Use**

Intermittent

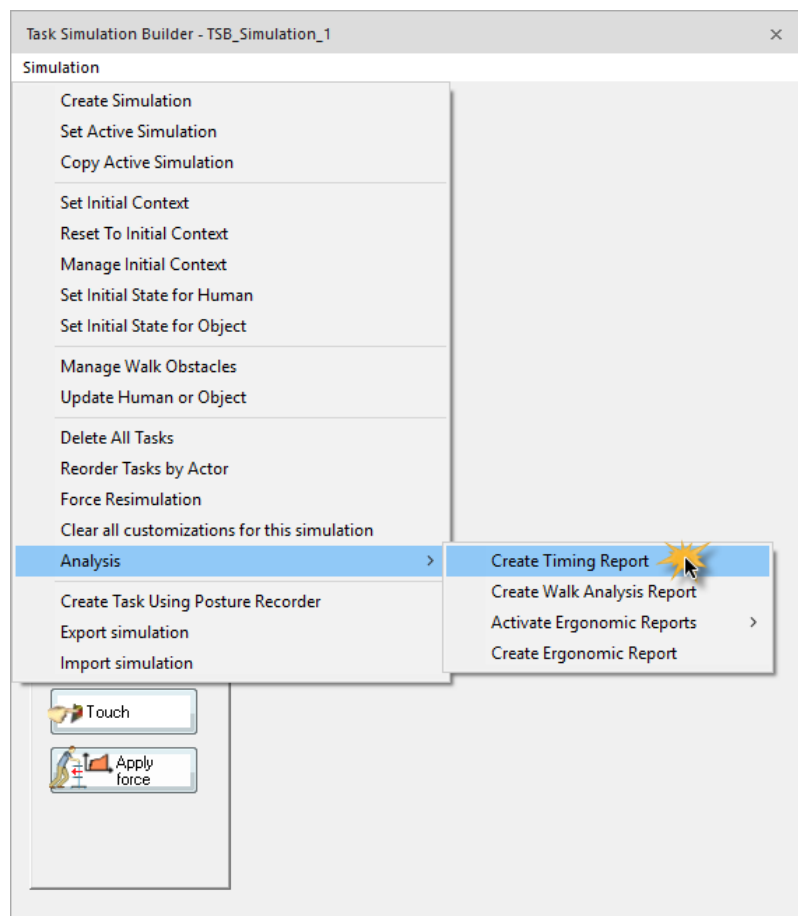
Static or Repeated

Shocks

OK Cancel



## 8) Timing Report (工时报告)



**Total Simulation Duration: 32.3s**

**Jill**

Task	Action	Duration (s)	Code
Get_PartPrototype_Jack	Walk	1.45	W4FT
	Turn_Body	0	TBC1
	Bend_And_Reach	1.674	B + R29.737A(b)
	Grasp	0.072	G1A(b)
<b>Put_PartPrototype_Jack</b>			
Pose_Jack	Arise_From_Bend	1.148	AB
	Walk	6.74	W18FT
	Turn_Body	0	TBC1
	Bend_And_Reach	1.717	B + R33.385A(b)
	Release	0.072	RL1(b)
<b>Get_PartPrototype_Jill</b>			
Put_PartPrototype_Jill	Arise_From_Bend	1.148	AB
	Walk	5.938	W16FT
	Turn_Body	0	TBC1
	Bend_And_Reach	1.645	B + R27.804A(b)
Pose_Jill	Grasp	0.072	G1A(b)
	Arise_From_Bend	1.148	AB
	Walk	5.9	W15FT
	Turn_Body	0	TBC1
	Bend_And_Reach	1.548	B + R20.072A(b)
<b>Pose_Jill</b>			
	Pose	1	Pose

基于标准人体模型、符合实际的动作序列定义以及与物理空间尺寸一致的虚拟空间，通过Process Simulate中动作模拟得出的人员操作工时具备一定的参考意义---代表具有中等熟练程度的操作人员完成该项任务的时间。

## 9) ForceSolver(受力分析)

### 概述

Force Solver(受力分析)工具可以认为是静态强度预测和下背部分析工具的混合体，同时具有两个工具的主要功能。通过该工具：

- 1) 可以预测出工人在某特定姿势下的最大可承载力。
- 2) 输入手部受力并调整大小，Force Solver工具实时自动计算关节的受力情况，一直到受力超出合理限定。

ForceSolver(受力分析)与Static Strength Prediction(静态强度预测)和Lower BackAnalysis(下背部分析)不同之处在于，其不用事先定义受力，而会自行计算出受力情况，这使得分析步骤得以简化。

### 输入选项

The screenshot shows the 'Options' dialog box for the Force Solver tool. It contains several sections with adjustable parameters:

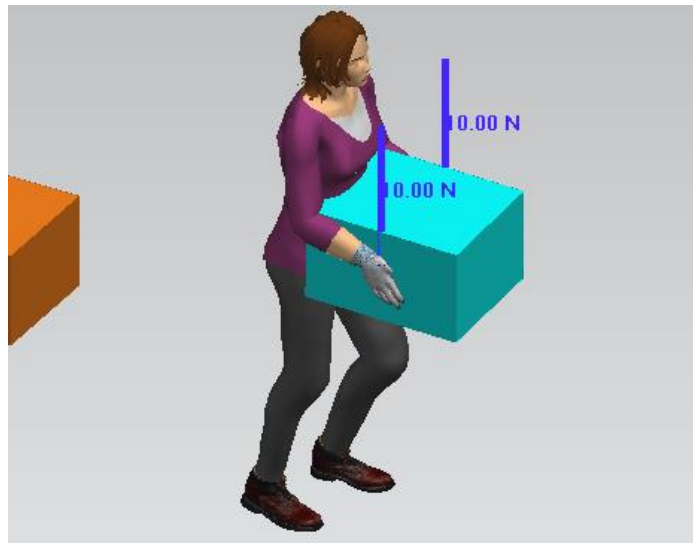
- Angle Convention:** Radio buttons for 'Jack' (selected) and 'SSP'. A red circle highlights the 'SSP' option, with a callout: '定义可接受人群比例阈值'.
- Strength:** A 'Percent capable threshold' set to 75. A checkbox for 'Use frequency/duration compensation' is unchecked. A callout points to this checkbox: '勾选是否考虑力的频率/周期'.
- Lower back:** Three input fields for limits: 'Compression limit (N): 3400', 'Anterior-posterior shear limit (N): 1000', and 'Lateral shear limit (N): 1000'. A callout points to the 'Anterior-posterior shear limit' field: '定义下背部受力阈值'.
- Solve:** Two input fields for load ranges: 'Starting load (N): 10' and 'Maximum load (N): 300'. A callout points to the 'Maximum load' field: '定义力的求解范围'.

At the bottom of the dialog are buttons for 'Reset to default', 'Apply', and 'Cancel'.



# 9) ForceSolver(受力分析)

## 报告解读



输入/查询  
手部受力

开始求解

当前受力能接受  
人群比例  
(阈值可定义)

定义身体  
支撑状况

ForceSolver工具不像其他工具一样，有专门的结论分析页面，在分析其结果时，需要直接观察其计算数据和表格得出结论。

单击Solver后，Forces(受力)一栏中会出现计算出最大受力，代表工人在这个姿态下手部最大可以承受的外力。

从Ergonomics Analysis栏可以得到受力分析的主要数据和结论，尤其需要注意观察表格中的颜色，在受力发生改变时，表格中数据和颜色也会相应改变。其中，红色方格代表这个动作无法维持而且无法继续增加受力；黄色方格则是代表在该姿势下这个关节此时的受力到达了临界值；绿色方格指示的是这个受力可以接受而且可以继续施加受力。

载荷频率及  
周期 (可选)

关节或身体部  
位屈曲 (可选)

结论：当前姿势  
最大可承受外力

The screenshot shows the 'Solver - Jill' window with the following sections:

- Forces:** Left hand and Right hand, both set to 84.00 N, 8.6 kg at palm.palmcenter.
- Support:** Force distribution strategy: Two Feet; Supporting hand: None; External support: None.
- Time and Frequency:** Freq/cycle: 1; Cycle time(sec): 60; Freq/min=1.0; Duration: <0.2 sec.
- Ergonomic analysis table:**

Joint/Axis	Capabl (%)	Use	Moment (Nm)	Muscle Effect	Angle (deg)	Strength Mean (Nm)	Strength StDv (Nm)
R Wrist Flexion	99.8	✓	-0.7	FLEXN	3.8	7.5	2.4
L Wrist Flexion	99.7	✓	-0.8	FLEXN	-13.9	7.2	2.3
R Wrist Deviation	97.8	✓	-2.6	RAD	-24.4	7.1	2.3
L Wrist Deviation	98.7	✓	-2.2	RAD	-5.4	7.6	2.4
R Wrist SuPr	99.6	✓	0.5	--	45.9	--	--
L Wrist SuPr	99.7	✓	0.4	--	-3.1	--	--
R Elbow	99.9	✓	-5.8	FLEXN	2.6	30.2	7.9
L Elbow	99.1	✓	-10.4	FLEXN	2.6	27.3	7.2
R Shoulder AbAd	99.9	✓	-9.3	ABDN	0.0	42.8	11.3
L Shoulder AbAd	95.8	✓	-21.4	ABDN	0.0	39.2	10.3
R Shoulder FwBk	99.9	✓	0.4	--	0.0	--	--
L Shoulder FwBk	99.8	✓	-1.4	FWD	0.0	40.1	13.7
R Shoulder Humeral	100.0	✓	-0.2	--	0.0	--	--
L Shoulder Humeral	100.0	✓	-1.1	LAT	0.0	25.0	6.5
Trunk Flexion	90.2	✓	-177.8	EXTN	34.8	321.8	111.1
Trunk Bend	100.0	✓	-7.9	RIGHT	-0.3	207.9	47.3
Trunk Twist	99.9	✓	3.2	CCW	-7.6	54.8	16.6
R Hip	73.8	✓	-93.3	EXTN	100.7	136.3	51.5
L Hip	75.2	✓	-101.3	EXTN	100.7	136.3	51.5
R Knee	99.7	✓	3.9	EXTN	64.3	114.3	39.6
L Knee	99.9	✓	-1.9	FLEXN	64.5	54.6	17.5
R Ankle	98.0	✓	-40.9	EXTN	11.5	93.5	25.6
L Ankle	97.3	✓	-44.5	EXTN	12.4	94.3	25.8

# 10) Arm Strength Evaluation (臂力评估)

## 概述

Process Simulate 14.0.2版基于LaDelfa和Potvin(2017)的研究, 引入了一种新的Arm强度评估工具, 为与强度相关的评估提供了额外的见解, 它可以在装配力限制等方面提供指导。与基于孤立肌肉群强度的模型相比, 臂力评估方法通过考虑手的位置、力的方向、人体测量和重力, 以整体的方式评估臂部肌肉的强度。

## 计算方法

计算指定的人体模型在握住物体时(或任何其他力作用于其手上时), 其手臂所能施加的最大力。

Arm的强度评估工具可以做到:

- 1) 按指定可接受人群比例, 计算当前姿势下上臂受力的最大值;
- 2) 计算能够接受当前上臂载荷的人群比例;
- 3) 根据使用频率和持续时间计算当前姿势下的上臂最大可承受载荷。

考虑频率及周期情况下, 上臂最大可承受载荷计算

The screenshot shows the 'Arm Strength Evaluation (Arm Force Field)-Jack' dialog box with the following fields and values:

- Manual arm strength: Percent capable: 75 %
- Arm strength for this scenario is: Left: - N, Right: 257.37 N
- Current load: Left: 0.00 N, Right: 14.71 N
- Percent capable: Left: - %, Right: 99.97 %
- Maximum acceptable force (MAF):  Compute MAF based on effort frequency and duration
- Frequency: 1.000 efforts/minute
- Duration: 3.000 seconds/efforts
- Maximum acceptable force: Left: - N, Right: 131.99 N

Annotations in Chinese:

- 当前姿势下上臂受力的最大值 (Current maximum force under current posture)
- 当前承受载荷 (Current load)
- 当前载荷适用人群比例 (Proportion of population that can tolerate current load)
- 动作频率 (Action frequency)
- 动作周期 (Action cycle)
- 计算结果 (Calculation result)