IME 454: SENIOR CAPSTONE GROUP PROJECT

REAR AXLE LINE ERGONOMIC ASSESSMENT

ABSTRACT

The objective of this project is to analyze the rear axle load operation at Android Industries. As Android is advancing, they have requested us to look into potential solutions to both resolve the ergonomic issues related to moving the lift-assist, as well as assume a flexible floor plan as the rear axle line will be expanding from nine (9) different parts to seventeen (17). An ergonomic study was completed and the team considered various different analyses including the ART Tool, 3DSSPP, and Liberty Mutual Manual Materials Handling Equations. After analyzing the line, interviewing operators, recording cycle times, and obtaining process videos, the team was able to analyze the current setup. From the information, it could be determined that the current process shows an elevated risk of injury for the majority of men or women. The risk score is driven due to the large forces required to push/pull the components from the dunnage racks to the workstation. However, by replacing the current lift assist with one that has some powered horizontal motion the forces could be minimized, reducing the pain of operators, and allowing for more axle components to be added to the operation.

Authors

Wyatt Moser **Chloe Wegener** **Olivia Wright**

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INTRODUCTION

The current rear axle line process requires operators to use a vertical lift-assist to move the ~800lb components to the assembly line. The lift-assist helps the technician by lifting and lowering the axles while the worker manually guides the assist horizontally. This sequence requires a substantial initial force to get the mechanism moving, a significant walking distance, and continuous pushing to move the component across the floor. Android Industries, LLC is hoping to expand the current operation from nine (9) axle types to 17. The goal of the collaboration with the team from Kettering University is to perform various ergonomic assessments to pinpoint the pain points of the operator to adequately suggest a more comfortable and efficient process that can be expanded for the new parts being added to the operation.

After an initial meeting with the client, the Kettering team proceeded to collect data from two (2) shifts during the week at the site. Ergonomic videos were taken to properly perform a cycle-time analysis. Additionally, the team collected trial push & pull forces from both male and female test subjects to be considered in various ergonomic assessment tools available. Ultimately the team decided on three (3) main numerical software for further calculation and determination. Once the minimum and maximum forces were determined, the team worked to calculate the distance from the current furthest rear axle dunnage racks to the workstation. It could be estimated that the total cycle time for the operator's process was 61.8 seconds. In order to fulfill Android's target takt time of 60 parts per hour, they must get the task below 60 seconds per component. Communicating with Android-approved vendors, the Kettering team is ending their academic term by proposing their best recommendation for an ergonomic and cost-effective mechanism capable of upscaling.

Figure 1: ***A collection of images from the job site of the rear axle line operation and current lift-assist.***

ERGONOMIC ANALYSIS

Methodology

Three (3) different ergonomic assessment tools were used to analyze the ergonomics of the Rear Axle job and assess the risk level. The **Assessment of Repetitive Tasks (ART)** Tool, Liberty Mutual Insurance application, and 3DSSPP Software were used to complete this. To obtain the inputs needed to complete these applications, a cycle time study was conducted. Additionally, a Mark-10-Ergonomics Test Kit Force Gauge was used to obtain the initial and sustained forces, while camera videos/photos were taken of the operation.

Liberty Mutual Ergonomics

After collecting Push/Pull Force data from the Android facility and using the Rear Axle Layout axles to obtain maximum and minimum walking distance (*83ft, 14.9ft*), the information was imputed into the **Liberty Mutual Insurance's Manual Materials Handling (LMMMH)** analysis tool to calculate the percentage of the population able to work this station. This application is used to assess jobs that require carrying, lifting, pulling, or pushing. The output of the tool indicates the percent of the population that can be expected to do a specific task without "overexertion." The goal is to design jobs that are acceptable to at least ninety percent of the female population, as it is less likely to be a danger (*Snook, et al., 1978, Marras, et al., 1999*). After completing the Liberty Mutual Analysis, it can be determined that the current process is not safe for the majority of men or women. Currently, the LMMMH estimates that less than 1% of the female population is able to complete the task (for eight (8) hours at a time) without straining themselves.

One of the main inputs for LMMMH is the number of pushes and pulls per minute, which was determined to be four (4). To collect the forces for the push/pulls, the Marc10 tool was used to obtain the initial and sustained forces of pushing the lift assist. It was estimated there were a maximum initial force of sixty-nine (69) pounds and a minimum of fifty-one (51) pounds, as for sustained force it was determined to be roughly twenty (20) pounds.

After this, the team wanted to test the population percentiles, but due to the differences in initial forces, distances walked, and other factors that vary operator-to-operator, a maximum and minimum case was created. The maximum analysis included the furthest placed dunnage rack at 83ft and a maximum initial force of 69 lbs. The minimum case factored in a walking distance of approximately 15ft, and closer to 51 lbs of initial force.

Gender	Initial Force %	Sustained Force %
Males	4%	90%
Females	1%	1%

***Figure 2:* Liberty Mutual Maximum Case Results**

From these calculations and assumptions, it was determined that for the maximum case, only men in the fourth percentile are able to endure the initial push to move the axle/lift without over-exerting themselves, while men in the ninetieth percentile could withstand the sustained force. However, according to LMMMH, no females were able to undergo this position without overexerting themselves as presented in the figure below. (*Figure 2*).

Gender	Initial Force %	Sustained Force %
Males	63%	90%
Females	1%	1%

***Figure 3:* Liberty Mutual Minimum Case Results**

Additionally, for the minimum case in Figure 3, LMMMH established that more men, of the sixty-third percentile, were able to undergo the initial force of the rear axle. However, even in the minimum case women were unable to complete the job without overexerting themselves. Still, LMMH assumes the job is eight (8) hours, while the running time is three (3) hours.

Gender	Initial Force %	Sustained Force %
Males	83%	84%
Females	77%	71%

***Figure 4:* Liberty Mutual Optimal Case Results**

However, in the scenario where the vertical height of the handle changes from above the operator's head (*70 inches*) to average elbow height (*45 inches*) and decreases the initial force to 38lbs, the female population percentile to seventy-seven Thus, lowering the vertical height and decreasing the amount of initial force as represented in Figure 4.

Unfortunately, there are limitations to the Liberty Mutual tool. LMMMH is unable to differentiate the number of hours worked, different forces used per pull/push, and additionally the different vertical heights. Thus, the project results are not precise.

3DSSPP

The **3DSSPP Ergonomics Tool** was developed by the University of Michigan to predict the strength requirements for several activities including push and pull movements. These movements are specific for heavy material handling and assume that acceleration is minimal. Thus, with the movement of ~770 lb axles, 3DSSPP provides relevant information when coupled with other ergonomic assessment tools. When assessing the forces needed to push the axle, the force was divided by two (2) and then assigned to the left and right hand For example, if the average force to move the axle was 30lbs then 15lbs was assigned to the left hand and 15lbs assigned to the right hand. Stresses and strength capacities were simulated by taking the workers' postures and creating a representation in the application. In 3DSSPP the model used calculates the strength capacity based on a 50th percentile male and females

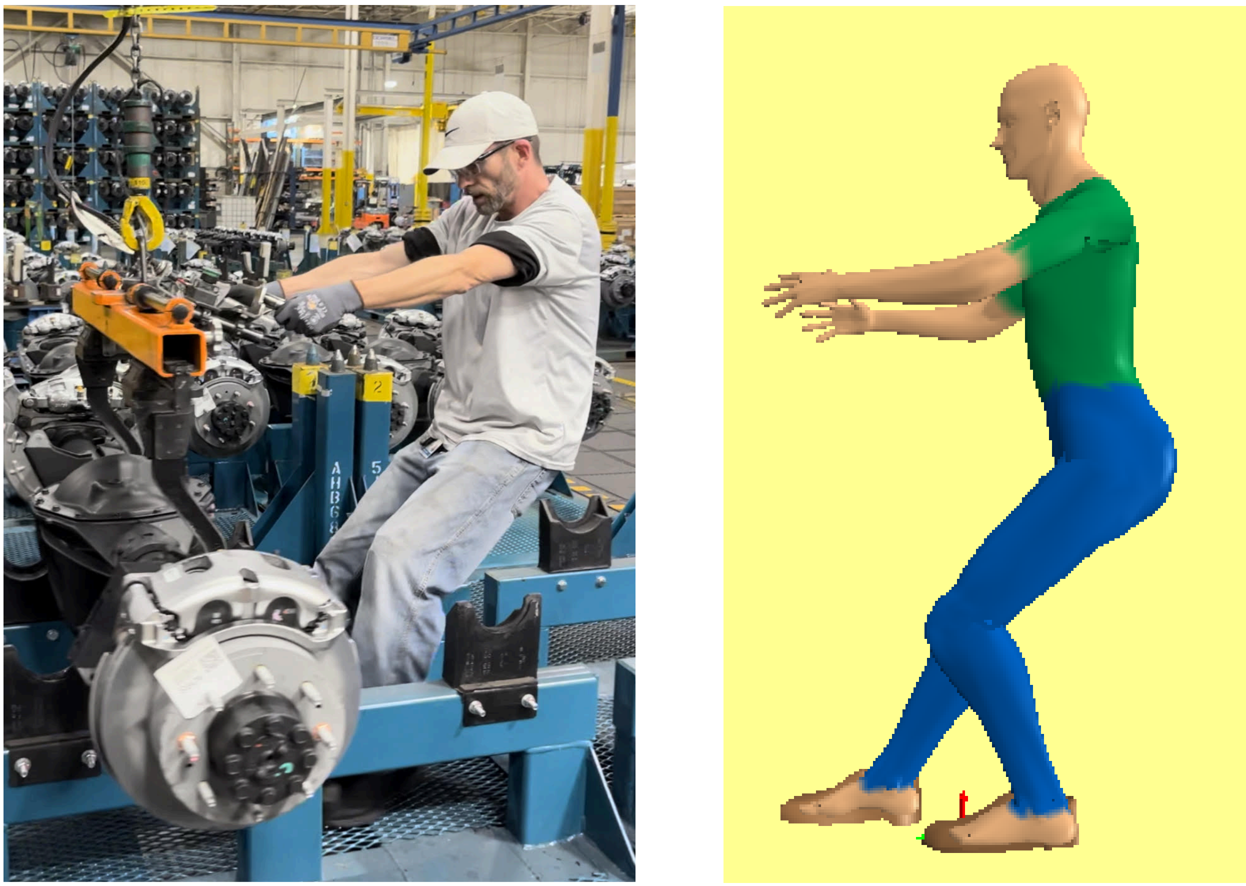

***Figure 5:* 3DSSPP Pull Comparison**

Force	Gender	Lower Back Compression	Wrist	Elbow	Shoulder	Torso	Hip
Average (59.94lbs)	*Male*	190	99	100	98	100	100
	Female	230	98	99	81	96	99
Minimum (51.75lbs)	*Male*	152	99	100	99	100	100
	Female	189	99	99	88	98	99
Maximum (69.35lbs)	*Male*	234	98	100	97	100	100
	Female	279	98	99	71	94	98

***Figure 6:* 3DSSPP output table on Pull strength capacity expressed as a percentage**

By analyzing the pull data from 3DSSPP we can see that the pulling work is manageable by both a 50% male and female. In fact, the only problem area is on the pull force for females where the strength capacity for the shoulders ranges from 71% to 88%. This is concerning as most work is designed with the idea that 90% of the female population could perform a task. Furthermore, these results show that the risk of back injuries are low as the Lower Back Compression is in a safe range.

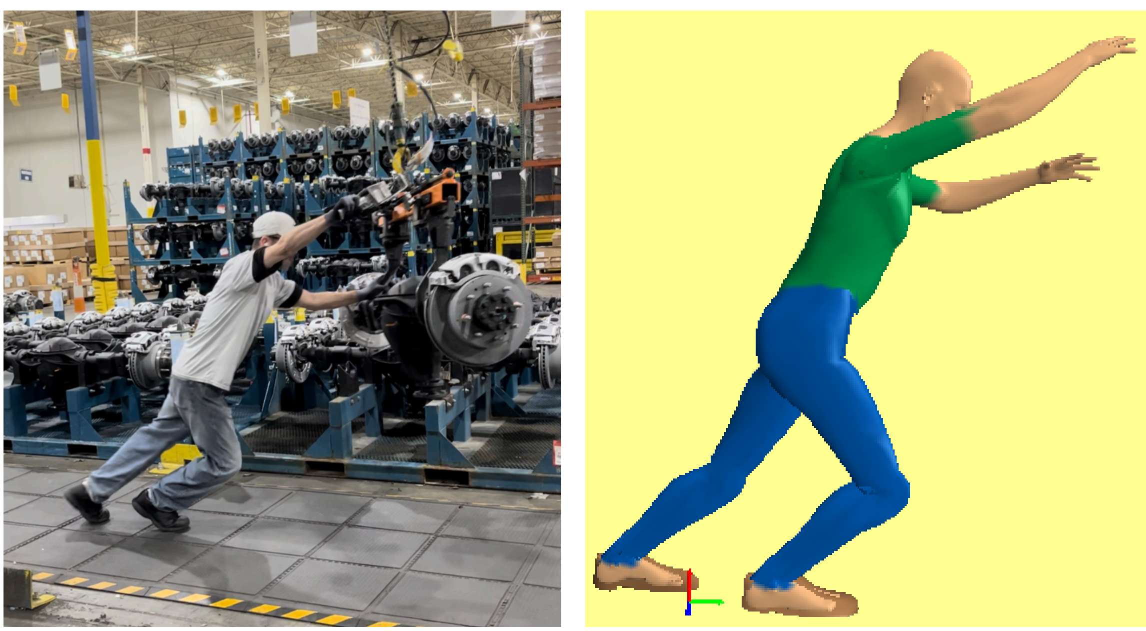

***Figure 7:* 3DSSPP Push Comparison**

Force	Gender	Lower Back Compression	Wrist	Elbow	Shoulder	Torso	Hip
Average **(39.5lbs)**	*Male*	586	96	100	99	72	70
	Female	533	94	97	95	50	28
Minimum **(20.85lbs)**	*Male*	495	99	100	100	87	86
	Female	428	99	100	99	77	68
Maximum **(63.8lbs)**	*Male*	692	82	98	98	44	42
	Female	663	74	79	79	17	3

***Figure 8:* 3DSSPP output table on Push strength capacity expressed as a percentage**

By analyzing the pull data from 3DSSPP we can see that the pulling work is manageable by both a 50% male and female. In fact, the only problem area is on the maximum pull force for females where the strength capacity for the shoulders is at 70%. While this is somewhat concerning, most work is designed that 75% of the female population could perform a task and the pull data suggests that this job falls in line with this.

When analyzing the push data, the problem areas begin to present themselves more. The average force needed to move the axle, only 70% of men could handle the stress on their hips. Furthermore, only 72% of men could handle this on their torso which is the main problem area. This then translates into the female statistics of only 28% of the average women working with this stress on their hips and 50% of them on their torso. These statistics show that the Rear Axle Load line is below what is considered acceptable for stress on a workstation.

The maximum push force, while not experienced on every cycle, shows that there is a small percentage of the workforce that should be doing this job. For men, only 44% can work with this on their torso while 42% can handle the force exerted on their hips. In females there is only 3% that can manage in terms of the force on the hip. This number slightly improves with the torso, placing the strength capacity at 17%.

With these factors in mind, the pull motion is not a reason for changing the process to improve ergonomics. The push motion is the main factor for why changes need to be implemented. The maximum push force on the axle may not be experienced every cycle, however, it is still experienced no matter how small and could lead to issues over time. Furthermore, with the low strength capacity for women, we can see that the job is not designed for everyone in mind. Even if the hunt is for men, the job would still be overly physical as only 70% of the average male should be completing the task.

Assessment of Repetitive Tasks (ART) Tool

The ART tool is designed to help individuals and companies assess the risks associated with repetitive tasks, specifically in the upper body. This tool allows employers to assess the risk factor of employees developing upper limb disorders as well as meet any legal requirements associated with these disorders. The final use for this tool is to prioritize the repetitive tasks that need to be improved.

To make these recommendations, the ART tool uses a variety of factors including frequency of the motion, the force associated with the movement, awkward postures in the back, arms, and neck, as well as other factors to consider such as breaks. Below are the images associated with some of the factors along with the score associated with each factor. In the below tables, the color code represents areas that need improvement. Green represents that the area does not need further investigation. Yellow shows that the area may create issues for the work and needs further ergonomic assessment. Red indicates the risk factor presents an immediate issue and further investigation is required.

Risk Factors	Left / Right Arm	
	Color	Score
A1 Arm Movements	Green	0
A2 Repetition	Green	0
B Force	Red	12
C1 Head/neck posture	Yellow	1
C2 Back posture	Red	2
C3 Arm Posture	Red	4
C4 Wrist posture	Green	0
C5 Hand/finger grip	Green	0

***Figure 9:* ART Assessment 1**

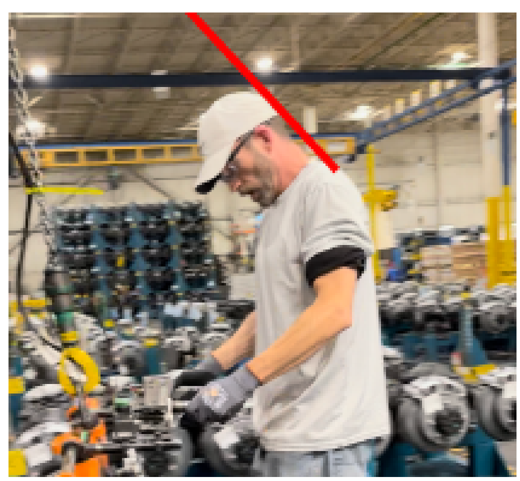

Figure 10: C1 - Neck Posture

Figure 11: ***C2 - Back Posture***

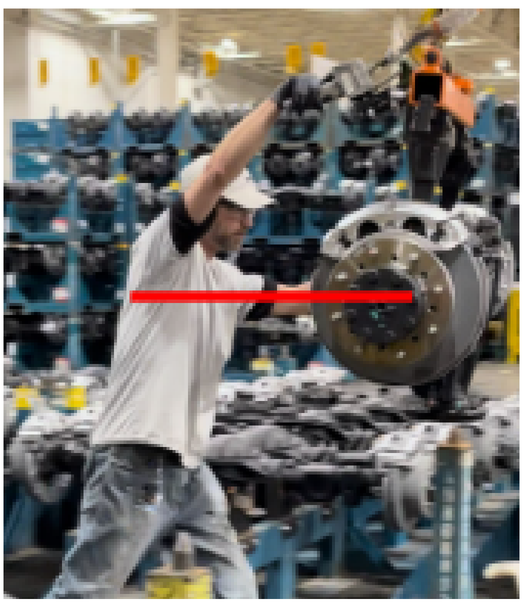

Figure 12: ***C3 - Back Posture***

Risk Factors	Left / Right Arms	
	Color	Score
D1 Breaks		4
D2 Work pace		1
D3 Other Factors		1
Task Score		25
D4 Duration Multiplier		X 0.75
Exposure Score		18.75
D5 Psychosocial factors: **N/A**		

Figure 13: ***ART Assessment 2***

When examining the neck posture, the ART tool defines the score of one as a position that is held for 15% to 30% of the time that the action is being performed. This percentage of time is representative of the time that the operator takes to look down and align the end of the lift assist with the axle and when the operator must look down to align the axle that is on the lift assist to the cart. An example of this posture can be found in Figure 10. Next, a red color back posture with a score of two (2) is defined as the back being bent or twisted more than 20 degrees past neutral. This bend can be exhibited in Figure 11. The highest score of 4 was assigned to the arm posture due to the location of the arms during a majority of the task. For this score, the ART tool defines this posture as arms that are held at chest height or above. This is represented by the photo taken in Figure 12. Finally the ART tool is defined when the job is monitored and the effort and force that the operator appears to be putting in is extreme. For the Rear Axle Loading job a score of 12 was assigned due to the high effort being shown only 40% to 60% of the time. These scores are represented in Figure 13.

Breaks are the next factor that the ART tool examines. Operators usually rotate out of the load cell or take a break every three hours. This is in line with the score of four which states that the operator works this position for more than two hours but less than three hours without a break. Next, the work pace is defined as a score of one (1) as the operators that were interviewed said that it can be difficult to keep up with the work. This is aligned with the ART tools definition of a score of one (1). Finally, other factors include things such as the operator's use of gloves, hammers, or other tools that can vibrate the arm. When examining the line, it was also noted that all operators wore gloves, which adds a score of one (1).

Exposure Score	Proposed Exposure Level	
0-11	Low	*Consider individual circumstances*
12-21	Medium	*Further investigation required*
22 or more	High	*Further investigation required urgently*

Figure 14: ART Tool presenting a final exposure score of 18.75, which requires further investigation.

Figure 14 then shows that this score means that the job needs to be investigated into any improvements that can be made. For example, fixing factors with a red color associated with the task would be areas to improve to bring down the score. By improving factors such as back and neck posture and the force that is exerted would make the station safer and the operator less susceptible to upper body injuries.

RESULTS & SOLUTIONS

After the cycle time study was completed, it was estimated to be a twenty-eight (28) second walking time to reach the farthest dunnage (83 ft away). If instead of implementing a conveyor, the layout was extended to fit all seventeen (17) different axle types, the total walking distance would be one hundred and twenty-nine (129) feet. The estimated walking time would increase to forty-two (42) seconds. This would make the total cycle time to be roughly sixty-two (62) seconds if the operator collects an axle from the farthest dunnage. Thus, by implementing a new lift assist, the job may be able to be completed within cycle time.

CONCLUSIONS AND RECOMMENDATIONS

The best opportunity for improvement in regards to reaching the goal of 75% percentile of the female population being able to complete this task is to acquire an Intelligent G-Force Lift Assist Device which can add power to move the rear axles with slight pressure from an operator. This solution will help the operator not use as much force and likely lower the vertical wrist height of the pulls and pushes, increasing the percentile of females who are able to complete the task. Safe workplace ergonomics is important because it helps to ensure that employees are able to work comfortably and safely, without putting themselves at risk of injury or other health problems. Good ergonomics can help to reduce the risk of musculoskeletal disorders, such as carpal tunnel syndrome, back pain, and neck pain, which are common among workers who spend long hours at a desk or in front of a computer. In addition, ergonomically designed workplaces can help to increase productivity and reduce absenteeism, as employees who are comfortable and healthy are more likely to be motivated and engaged. Overall, safe workplace ergonomics is essential for creating a healthy and productive work environment.

REFERENCES

"Assessment of Repetitive Tasks (ART) Tool." *HSE*, Health and Safety Executive, Mar. 2010, https://www.hse.gov.uk/msd/uld/art/index.htm.

Liberty Mutual Insurance. "Liberty Mutual Manual Materials Handling Population Percentiles." Accessed 12/13/2022. Net. Retrieved from https://libertymmhtables.libertymutual.com/

"3DSSPP." 7.1.3, VelocityEHS, 2020.

Appendix A: Initial Project Proposal

Overview

This project was assigned to Team 2 for Android Industries by Professor Justin Young from Kettering University. The overall team assignment is to change the floor layout to accommodate for the expanding number of axles (from nine to seventeen), eliminate the current high turnover rate, and if feasible, reduce costs and cycle time. Over the course of this project, Team 2 will investigate possible ergonomic improvements of the line and identify semi-automated and automated solutions.

Scope

This capstone project encapsulates the applications of Industrial Engineering learned through Kettering University's undergraduate program. The team will need to apply learnings in ergonomics, user-interface design/testing, project management, and operations research. Background in workplace efficiency and user-friendly systems will be beneficial to the group. Additionally, this project will include an economic assessment of the organization before and a projection after the solution is implemented.

Goals/Aims

The aim of this capstone is to apply to learnings of the team's undergraduate career to accomplish an external client's goal. This project will be to update the current assembly line to a semi-automated or fully automated line with a production layout change. Considering current space, time, and cost constrictions, the hope for the conclusion is a table or conveyor system capable of presenting or presenting axles for the operator from the sequence racks. Additionally, the company is looking to increase their dunnage racks from 9 to 14, so ideas for reconfiguration of more parts needs to be considered.

Project Constraints

- Available Plant Space
- Axle Weight
- Group timing and availability
- Pre-setting of the dunnage
- Ergonomics
- Tact time with increase of axles

Deliverables

- Project Proposal
- Gantt Charts
- Cycle Time Study Analysis
- Ergonomic Study
- Assessment Chart
- Midterm Proposal Update
- Cost-Analysis
- Final Report & Solutions
  - Semi-Automated
  - Automated

Contacts

Austin McGuire <*amcguire@android-ind.com*>
Barry A. Clark <*baclark@android-ind.com*>
Catie McKown <*cmckown@android-ind.com*>
Brian Leahy <*bleahy@android-ind.com*>

Appendix B: Liberty Mutual Tables

Gender	Initial Force %	Sustained Force %
Males	4%	90%
Females	1%	1%

Figure 2: Liberty Mutual Maximum Case Results

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Figure 3: Liberty Mutual Minimum Case Results

Gender	Initial Force %	Sustained Force %
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Females	77%	71%

Figure 4: *Liberty Mutual Optimal Case Results*

Appendix C: Assessment of Repetitive Tasks Tables

Risk Factors	Left / Right Arm	
	Color	Score
A1 Arm Movements		0
A2 Repetition		0
B Force		12
C1 Head/neck posture		1
C2 Back posture		2
C3 Arm Posture		4
C4 Wrist posture		0
C5 Hand/finger grip		0

Figure 9: *ART Assessment 1*

Risk Factors	Left / Right Arms	
	Color	Score
D1 Breaks		4
D2 Work pace		1
D3 Other Factors		1
	Task Score	25
D4 Duration Multiplier		X 0.75
	Exposure Score	18.75
D5 Psychosocial factors: **N/A**		

Figure 13: *ART Assessment 2*

Appendix D: 3DSSPP Tables

Force	Gender	Lower Back Compression (lb)	Wrist	Elbow	Shoulder	Torso	Hip
Average (59.94lbs)	*Male*	190	99	100	98	100	100
	Female	230	98	99	81	96	99
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	Female	279	98	99	71	94	98

Figure 6: *3DSSPP output table on Pull strength capacity expressed as a percentage*

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