THE ERGONOMICS CENTER OF NORTH CAROLINA
Advancing the Science of Ergonomics in the Workplace™

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VIA E-mail: vep1@cdc.gov

March 4, 2011

Vern P. Anderson, PhD
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4676 Columbia Parkway
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Dear Dr. Anderson:

Thank you for your support of the Ergonomics Center of North Carolina (ECNC). It has certainly been a pleasure working with you over the course of the WRT Manual Materials Handling Demonstration Projects. Please find enclosed a report summarizing and detailing the Eastern Region Project (NIOSH Contract No: 214-2009-M-32436). The host site selected for this project was part of a large grocery store chain and was located in North Carolina.

Please feel free to review and pass along to the appropriate parties. Also, please do not hesitate to call should you have questions concerning this report, my direct line is (704) 483-2837. I look forward to hearing from you.

Best Regards,

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The Ergonomics Center of North Carolina
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WRT Manual Material Handling Demonstration Project: "Work Smart at the Right Height"

Eastern Region: NIOSH Contract No: 214-2009-M-32436

Prepared for

National Institute for Occupational Safety and Health

March 4, 2011

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1. Executive Summary

Background Summary. The Ergonomics Center of North Carolina (ECNC) housed within North Carolina State University partnered with a large grocery store chain that has retail locations in the eastern region of the United States. The host site selected for this Eastern Region Project was located in North Carolina. The primary purpose of the demonstration project was to demonstrate the efficacy of manual materials handling (MMH) equipment in the retail trade sector that would reduce the bending, stooping, and overhead reaching associated with loading and storing materials in retail stores. More specifically, the purpose of this report was to outline the methods and show the ***Pre-*** versus ***Post-intervention*** results in terms of ergonomics risk, usability feedback, body discomfort, productivity, and estimated return-on-investment (ROI) for the interventions introduced and tested.

Methods Summary. Based on company incident data and management input, the Deli/Bakery Department Clerks were targeted for this MMH demonstration project. More specifically, the two processes of focus were the following:

1. *Deli/Bakery Clerk: Breakdown Pallets, Transfer, and Restock Deli/Bakery Department*
2. *Deli/Bakery Clerk: Meats Preparation*

Pre-intervention data collection consisted of on-site observation, task analysis, ergonomic risk evaluation, body part discomfort surveys as well as basic time studies of targeted process(es) to prioritize tasks based on ergonomic risk and time spent (% of process) in an attempt to maximize potential ergonomic and productivity benefits. Interventions to trial were researched, brainstormed, proposed, and agreed upon by corporate and store-level personnel to gain buy-in on all levels of the company prior to introduction. ECNC worked with third party material handling equipment vendors to provide either "off-the-shelf" equipment or "retrofitted" equipment to the application or requested desires of the host site superstore. Once finalized and shipped to the host-site store in North Carolina, the equipment was introduced to store-level personnel and a brief training session was conducted to ensure proper use of equipment and address any safety precautions.

A six-week phase-in time was allocated to allow employees to gain experience using the new equipment and to minimize potential Hawthorne Effects prior to post-intervention data collection. Post-intervention data collection included the same protocol as previously stated in the "pre-intervention" phase, but also included equipment usability feedback from host-site personnel. Depending on the task type and applicability, pre- vs. post-intervention ergonomic risk differences were assessed using the Lumbar Motion Monitor and corresponding Low Back Disorder Risk Model[1,2,3], the 3-Dimensional Static Strength Prediction Program[5], the 1991 Revised NIOSH Lifting Guide[7,8], Liberty Mutual Manual Materials Handling Guidelines[6], and/or Rapid Upper Limb Assessment[4]. Final results were shared with both corporate and store-level stakeholders to promote buy-in, answer any questions related to the project, and to discuss path-forward details.

Results Summary. Two different interventions were introduced and evaluated at the host-site retail store in North Carolina (see Table 1.1):

1. Customized Self-Leveling Cart (spring-loaded)
2. Height Adjustable "High" Lift Cart (battery powered)

Table 1.1: ***Manual Materials Handling Interventions Tested***	
	
Customized Self-Leveling Cart (Spring-Loaded)	***Height Adjustable "High" Lift Cart (Battery Powered)***

Both interventions were trialed and evaluated for different applications. The customized self-leveling cart was used to load and transport perishable cartons (5 – 54 lb) from back room storage (pallets in coolers or freezers) to Deli/Bakery department storage (cooler or freezer shelves). The height adjustable "high" lift cart was used to load and transport heavy meat cartons (i.e. boxes of chicken, pork, turkey: 14 – 54 lb) from Deli/Bakery department storage to the preparation sink prior to cooking.

The customized self-leveling cart and height adjustable "high" lift cart were both routinely used by store personnel during Deli/Bakery department material handling activities. In summary, both interventions showed a reduction in ergonomic risk level, a reduction in reported discomfort, a slight improvement in productivity, and reported positive usability feedback by store employees.

***Conclusion Summary*.** While this project served as a pilot study involving a limited number of participants, equipment applications, and was conducted over a relatively condensed trial period, future studies are needed to help validate such equipment in the whole-sale and retail trade sector. However, pilot results from this study certainly show promise that such "load-elevating" equipment may have both ergonomic and productivity benefits in the retail trade sector.

2. Introduction

2.1 Background

Safety incidents are common among the retail trade sector. According to the Bureau of Labor Statistics, there were 4.3 injuries/illnesses per 100 full-time retail employees reported in 2008. Overexertion and strain/sprain injuries are the most common type and nature of incidents. Many of these incidents result from material handling activities such as lifting/lowering, carrying, and pushing/pulling. Eighty (80%) of employees in whole-sale and retail trade (WRT) engage in manual materials handling (MMH) tasks.

Therefore, the primary emphasis of the demonstration project was to ultimately reduce or potentially prevent overexertion injuries caused by material handling activities. Overexertion injuries leading to shoulder and back injuries are the leading musculoskeletal complaint, the most costly, and frequently the basis for the most lost time on a job. As a result, particular focus was placed on prevention of trunk and shoulder injuries for these tasks. Moreover, as this workforce ages and the workforce becomes more diverse (i.e., older, smaller, female, etc.), MMH activities that include bending, lifting and carrying pose a risk of musculoskeletal disorders (MSDs) as well as slips, trips, and falls.

2.2 Purpose

The purpose of this project was to undertake and complete the following three tasks:

(1) Identify a workplace in the WRT sector located within the **eastern region of the U.S.**
(2) Identify/select appropriate workplace solutions/best practices for one or more of those workplaces
(3) Implement and evaluate the intervention to determine its effectiveness.

The interventions tested herein included engineering solutions that would reduce excessive bending and/or eliminate the lift entirely for specific MMH applications. It should be noted that such devices are likely not the complete solution to MSD problems associated with MMH, but they do introduce new technology into jobs that have not changed in decades. Once newer MMH assisted equipment is introduced, the greater the opportunity to introduce additional lifting/supporting equipment to reduce the loading of flatbed carts, dollies and pallets.

In summary, to identify and demonstrate the value of a "breakthrough" intervention as it applies to retail environments was our ultimate goal. More specifically, the purpose of this report was to outline the methods and show the ***Pre-*** versus ***Post-intervention*** results in terms of ergonomics risk, usability feedback, body discomfort, productivity, and estimated return-on-investment (ROI) for the interventions introduced and tested.

3. Methods

3.1 Project Steps

The following steps were undertaken as part of the WRT MMH demonstration study:

1.	A retail host site was identified, corporate and store-level personnel were introduced to the project, and a basic timeline for project implementation was documented and approved
2.	Services agreement contract finalized between ECNC and host-site company finalized and approved through legal department and management stakeholders
3.	NCSU Institutional Review Board application submitted and approved to grant permission to collect objective and subjective data from host-site employees during intervention testing
4.	Reviewed host company injury/accident logs to help determine departments, job positions, and processes to focus on for implementing a MMH improvement
5.	Discussed with corporate, store-level and department management to get their feedback on processes to observe or focus on for MMH improvement
6.	Performed pre-intervention observation, task analysis, ergo risk factor analysis and confirmation as well as basic time study of targeted process(es) to prioritize tasks based on ergonomic risk and time spent (% of process) in an attempt to get the biggest bang for the buck from a potential ergo risk reduction and productivity improvement standpoint
7.	Reviewed current vendor products (e.g. MH solutions) on the market that may address the tasks of concern from pre-intervention analysis of current-state processes
8.	Proposed possible solutions to corporate and site-stakeholders to gain input on which MH solutions to trial
9.	Worked with MH vendor to provide existing product and/or retrofit MH solution to application/needs of client
10.	Introduced and trained host-site on the use of MH solution, allowed 6-week phase-in time before collecting post-intervention data
11.	Followed up with host-site during phase-in time to ensure that new equipment was being used and was functioning properly
12.	Performed post-intervention observation, task analysis, ergo risk evaluation, time study, and collected subjective feedback from workers on usability and body part discomfort
13.	Collected and analyzed company workers' compensation claim data to estimate potential return-on-investment (ROI) and payback periods for the interventions introduced
14.	Shared results with corporate and site stakeholders to promote buy-in and discuss path-forward / next-steps

3.2 Ergonomic Analysis and Evaluation

3.2.1 Lumbar Motion Monitor (LMM) and Low-Back Disorder (LBD) Risk Model

Figure 3.1. A worker wearing a lumbar motion monitor (LMM).

The Lumbar Motion Monitor (Figure 3.1), or LMM, was used to help evaluate the customized self-leveling lift cart. Pre- vs. post-intervention results were averaged across a minimum of 5 trials of the participant performing each of the evaluated tasks. The LMM is a lightweight exoskeleton of the spine that is worn during the performance of lifting and material handling tasks. The patented LMM (The Ohio State University) was developed to provide an accurate method of tracking dynamic back motion in three-dimensional space. The LMM, along with information on the work environment, was used to predict the level of low back disorder risk for a given task. The five trunk motion and workplace factors that make up the Low-Back Disorder Risk Model include:

- Lift frequency
- Maximum load moment
- Average twisting velocity
- Maximum lateral velocity
- Maximum sagittal flexion

More than 400 repetitive lifting jobs were studied in 48 varied industries to compile this risk model. Existing medical and injury records in these industries were examined so that specific jobs historically categorized as either high-risk or low-risk for reported occupationally-related low back disorder could be identified[1,2,3]. Ergonomic risk level to the back was determined for tasks defined by the following categories:

- Probability of High Risk Group Membership ≤ 30% = **Low** risk
- Probability of High Risk Group Membership 31-60% = **Moderate** risk
- Probability of High Risk Group Membership > 60% = **HIGH** risk

3.2.2 Three-Dimensional Static Strength Prediction Program (3DSSPP)

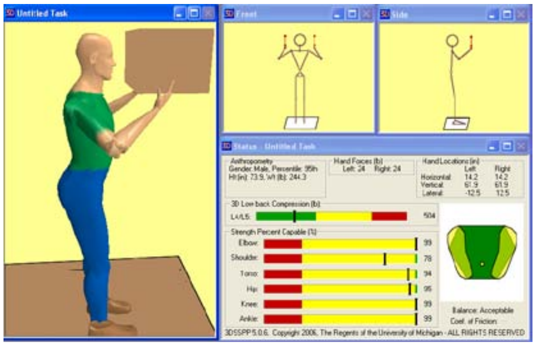


Figure 3.2. Screen capture of the 3DSSPP application. In the illustration above, a two-handed lift of 48 lbs is modeled using the anthropometry of a 95% male.

The 3DSSPP™ software (Version 6.0.4 used in this effort) developed by the University of Michigan was also used to evaluate ergonomic risk level. This software was used to statically model tasks, using limited female and male anthropometry, descriptions of posture and the force loading at the hands (Figure 3.2). This program was used to estimate the static compressive forces on the low back and the strength capability requirements of a given task. Based upon posture, anthropometry and the external load magnitude and direction at the hands, this software also estimates the required moments at multiple joints of the body and compares those computed moments to predicted mean strengths at each of the joints. Strength as expressed by the program is the ability to resist or generate a moment about a joint. The strength prediction equations are based upon gender and joint position and are independent of anthropometry and body weight.

3.2.3 Revised (1991) NIOSH Lift Equation

When the LMM was not appropriate to use due to space constraints and/or employee interference (e.g. using the height adjustable lift cart in the Deli/Bakery department coolers), the NIOSH Lifting Equation and 3DSSPP was used to assess pre- and post-intervention ergonomic risk level for the back. The NIOSH Lift Equation was created to help evaluate lifting activities in an attempt to prevent low back pain and injuries in workers whose job tasks require unassisted lifting of materials. The product of seven measurements provides the Recommended Weight Limit (RWL) for a specific task. The RWL is the weight, under the described conditions, that nearly all healthy workers could lift for a substantial period of time. The RWL is calculated from a Load Constant (LC) of 51 lbs. combined with six lifting multipliers. This load constant is considered to be the maximum load that nearly all healthy workers should be able to lift under optimal conditions.

The Lifting Index (LI) is a ratio that provides a relative estimate of the level of physical stress associated with a particular manual-lifting task. It is calculated by dividing the actual weight of the object being lifted (L) by the RWL (LI = L/RWL). With the LI, comparisons may be drawn regarding the physical stress of the lifting activity and a potential risk level associated with them. This information is useful in the prioritization of interventions when a program has a limited budget for control options. The general decision guideline for the Lifting Index is as follows:

- If **LI ≤ 1**, the lift is acceptable for nearly all workers (**Low** risk)
- If **1 < LI ≤ 3**, there is an elevated risk for some fraction workers - changes should be considered (**Moderate** risk)
- If **LI > 3**, there is an elevated risk for nearly all workers - lift should be redesigned (**HIGH** risk)

3.2.4 Liberty Mutual Manual Materials Handling Guidelines

A set of design tables for evaluating manual handling tasks produced by Liberty Mutual Insurance was utilized to assess risk levels for any carrying and/or pushing/pulling tasks. These guidelines and the acceptable weights or forces are based on psychophysical data. Given the task parameters, if the specific task was above or below the acceptable force or weight limit, the task was considered **HIGH** or **Low** risk, respectively.

3.2.5 Rapid Upper Limb Assessment (RULA)

Researchers at the Institute for Occupational Ergonomics at the University of Nottingham, Nottingham, United Kingdom developed the Rapid Upper Limb Assessment (RULA) tool. RULA was used as a task assessment tool for evaluating the shoulders, elbows and hands/wrists during pre-intervention task analysis and risk assessment for overhead or extended reaching. It was developed to accomplish the following:

- To provide a quick assessment tool for exposure to risk factors related to the upper limb disorders;
- To identify efforts associated with posture, force exertion and static or repetitive tasks that may contribute to muscular fatigue;
- To produce an outcome that could be included into a broader ergonomics assessment.

RULA uses basic descriptive guidelines to assign numerical values to postures and forces. These initial values were used to obtain a “Grand Score” which is the overall score of the evaluation. The Grand Score can range between 1 and 7 inclusive with higher scores indicative of higher risk for upper extremity MSD development (see below). When appropriate, RULA was used to compare tasks pre- and post-intervention for upper extremity risk:

- Grand Score ≤ **4**, Posture acceptable if not maintained or repeated for long periods (**Low** risk)
- Grand Score = **5-6**, Investigation and changes required soon (**Moderate** risk)
- Grand Score = **7**, Investigation and changes required immediately (**HIGH** risk)

3.3 Discomfort Survey

Participants were asked to rate their subjective level of discomfort on a 0 to 10 modified CR10 Borg scale[1] (*Appendix A*) for seventeen different body parts from their head to the feet. A rating of 0 = no reported discomfort and a rating of 10 = maximal discomfort. Discomfort ratings were collected at the beginning of the shift and every two hours thereafter over the course of their shift.

3.4 Usability Feedback

Usability feedback and comments were also recorded from employees that used the interventions. A usability questionnaire using a scale from 1 to 6 measuring strength of agreement (1 = strongly disagree to 6 = strongly agree) was administered to collect subjective feedback on how employees perceived the new equipment made the job safer, easier, and faster (*Appendix A*). Ratings were also given to push/pull ease, adjustability, and if employees recommended the intervention(s) to management and other retailers. Anecdotal comments were also recorded by employees on likes and potential improvement opportunities of equipment.

3.5 Productivity

Work sampling and time study techniques were used to calculate pre- vs. post-intervention productivity differences. Video was captured of processes and specific applications both pre- and post-intervention. Task analyses were performed to determine average task time differences across a set number of boxes/cartons loaded, transported, and unloaded. Total time savings for the application was then estimated by adding up the task time differences and multiplying by the average number of deliveries and/or process iterations that are typically performed by Deli/Bakery personnel on a daily basis.

3.6 Participants

Participants included experienced Deli/Bakery Clerks recruited from the , NC retail store. Volunteers had to have a minimum of 3 months experience in such positions to participate. Other criteria for exclusion were: (1) previous back or shoulder injury, (2) previous knee injury, (3) medical problems that would interfere with a person's ability to perform a repetitive lifting task, (4) under 18 or over 50 years old, and (5) unable to lift 50 lbs.

Verbal permission from area supervisors was sought prior to recruiting subjects. However, supervisors were not present during recruitment, and it was stated both verbally and in the Informed Consent Form that participation was voluntary and would not affect participants' employment.

In an effort to minimize process disruption and due to the fact that certain store employees were assigned to specific Deli/Bakery department tasks on a daily basis, it was only possible to collect data on a limited number of employees. In other words, since the chosen Deli/Bakery tasks for this project was assigned to one specific employee, pre- vs. post-intervention LMM, 3DSSPP, and time study data to evaluate the customized self-leveling cart and the height adjustable "high" lift cart was only collected on one specific participant for each intervention. Thus, statistical analysis was not performed on results.

4. Results

4.1 Problem Magnitude and Project Focus

Based on company incident data as well as corporate and store-level management input, the Deli/Bakery Department Clerks were targeted for this MMH demonstration project. According to 2009 company strain/sprain accident data, Deli/Bakery Department personnel accounted for 23.9% of incidents, 25.1% of lost-days, and 38.1% of restricted days, which was the highest of any other department. Among all strain/sprain incidents, the back resulted in the greatest percentage of incidents (44.1%) and accounted for 25.4% and 57.2% of lost and restricted days, respectively.

More specifically, the two processes of focus were the following:

- *Deli/Bakery Clerk: Breakdown Pallets, Transfer, and Restock Deli/Bakery Department*
- *Deli/Bakery Clerk: Meats Preparation*

4.2 Interventions Tested

Two different interventions were introduced and evaluated at the host-site retail store in , North Carolina (see Table 4.1):

1. Customized Self-Leveling Cart (spring-loaded)
2. Height Adjustable "High" Lift Cart (battery powered)

Table 4.1: *Manual Materials Handling Interventions Tested*	
Customized Self-Leveling Cart (Spring-Loaded)	***Height Adjustable "High" Lift Cart (Battery Powered)***
	
List Price: $2,000 to retrofit	**List Price:** $2,595
Specifications • Capacity: 750+ lb. • Drive: manual (push) • Lift: spring-loaded • Platform size: 24" W x 48" L • Raised height: 45" (no load) • Lowered height: ~13" • Spring chosen for application allowed the platform to fully compress with 250 lb. of load. This allowed *'level loading'* for the bottom half to bottom third of the load (e.g., 500 to 750 lb. total load). • Smooth rolling casters, no wheel locks	**Specifications** • Capacity: 220 lb. • Drive: manual (push) • Lift: electric (battery) • Platform size: 20" W x 31.5" L • Raised height: 51" • Lowered height: 13" • Vertical travel: 38" • Smooth rolling casters & floor lock

4.3 Customized Self-Leveling Cart (Spring-Loaded) Results

A summary of results from introducing the customized self-leveling cart is highlighted in Table 4.2 below.

Table 4.2: Summary of Results for Customized Self-Leveling (Spring-Loaded) Cart	
 **Self-Leveling Cart (Spring-Loaded)**	 **PRE-Intervention** →  **POST-Intervention**
Intervention Description	• A self-leveling lift cart (spring-loaded) was implemented to minimize back flexion when lifting cartons to/from flatbed carts during Deli/Bakery pallet breakdown in backroom and unloaded in Deli/Bakery department storage.
Application / Observations	• Used to load, transport, and unload perishable cartons (5 – 54 lb) from back room storage (pallets in coolers or freezers) to Deli/Bakery Department storage (cooler or freezer shelves).
Ergonomics Risk	• Ergo risk ↓ from **HIGH** to **Moderate** (Back)[2-4] for lifts to/from cart to carry height (heaviest weights) o Compressive force on spine ↓ **58%** from 1,723 lb to 723 lb if 54 lb wt. lifted[6] • Ergo risk ↓ from **Moderate** to **Low** (Back)[6,8-9] for lifts to/from cart to carry height (average weights) o Compressive force on spine ↓ **58%** from 1,278 lb to 537 lb if 20 lb wt. lifted[6]
Body Discomfort	• Reported Back, Shoulder, and Knee discomfort ↓ **≥30%** (1 associate)
Usability Feedback	• Strong positive usability feedback and highly recommended (2 associates)
Productivity	• Productivity ↑ **1.9%** (load & unload time) = **5.3 min savings/day**

4.3.1 Ergonomics Risk Results

A self-leveling lift cart (spring-loaded) was implemented to minimize back flexion when lifting cartons to/from flat-bed carts during Deli/Bakery pallet breakdown and unloading/supply replenishment activities. Store personnel used this device primarily for loading, transporting, and unloading perishable cartons (5 – 54 lb) from back room storage (pallets in coolers or freezers) to Deli/Bakery Department storage (cooler or freezer shelves). Ergonomic risk results are summarized for the self-leveling lift cart in Table 4.3 below.

Table 4.3: PRE- vs. POST-Intervention Ergonomic Risk Results (Self-Leveling Lift Cart)

Job Task	Analysis Tool Used	PRE-Intervention Results (with standard flat-bed cart)	POST-Intervention Results (with self-level lift cart)
Manual lift to/from bottom layer on cart to/from carry height (Loading in Back Room Storage and Unloading in Dept. Storage)	LMM / LBD Risk Model[2-4] (Back)	**HIGH risk** Probability of High Risk Group Membership for LBDs = **67.1%** (lift weight = 54 lb)	**Moderate risk** Probability of High Risk Group Membership for LBDs = **51.9%** (lift weight = 54 lb)
	3DSSPP[6] (Back)	**HIGH risk** Low back compressive force = **1,723 lb** Back strength % capable = **50%** (lift weight = 54 lb)	**Moderate risk** Low back compressive force = **723 lb** Back strength % capable = **79%** (lift weight = 30 lb)
	3DSSPP[6] (Back)	**Moderate risk** Low back compressive force = **1,278 lb** Back strength % capable = **79%** (avg. lift weight = 20 lb)	**Low risk** Low back compressive force = **537 lb** Back strength % capable = **94%** (avg. lift weight = 20 lb)

As shown in Figures 4.1 and 4.2 below, ergonomic risk differences were due in large part to reduced sagittal / forward flexion when the self-leveling lift cart was used. The horizontal reach distance and resultant maximum moment was also reduced slightly with the self-leveling lift cart. Average twist velocity and maximum lateral velocity remained relatively unchanged pre- and post-intervention.

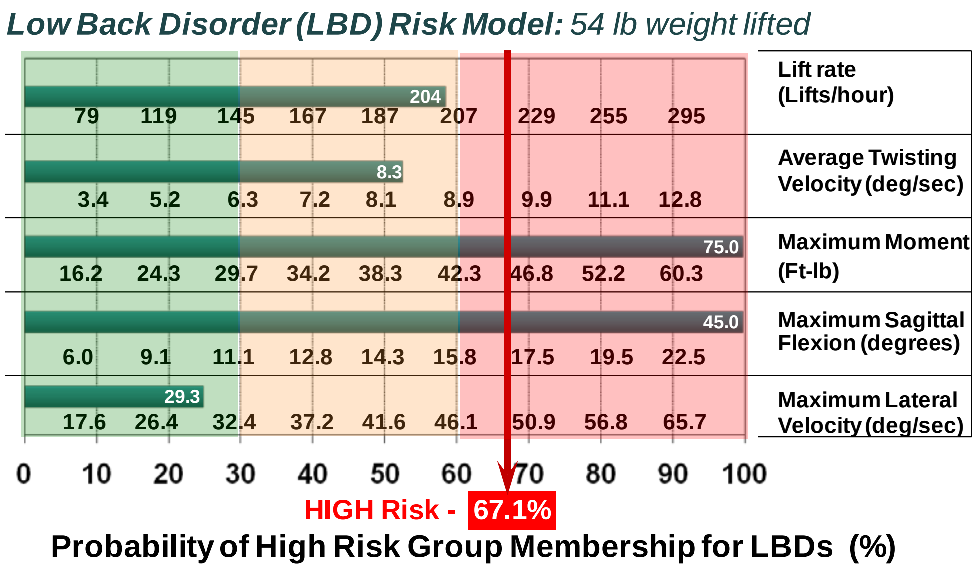


Figure 4.1: PRE-Intervention LBD Risk Model Results[2-4]. Lift carton (54 lb) to/from bottom of flat-bed cart to/from carry height.

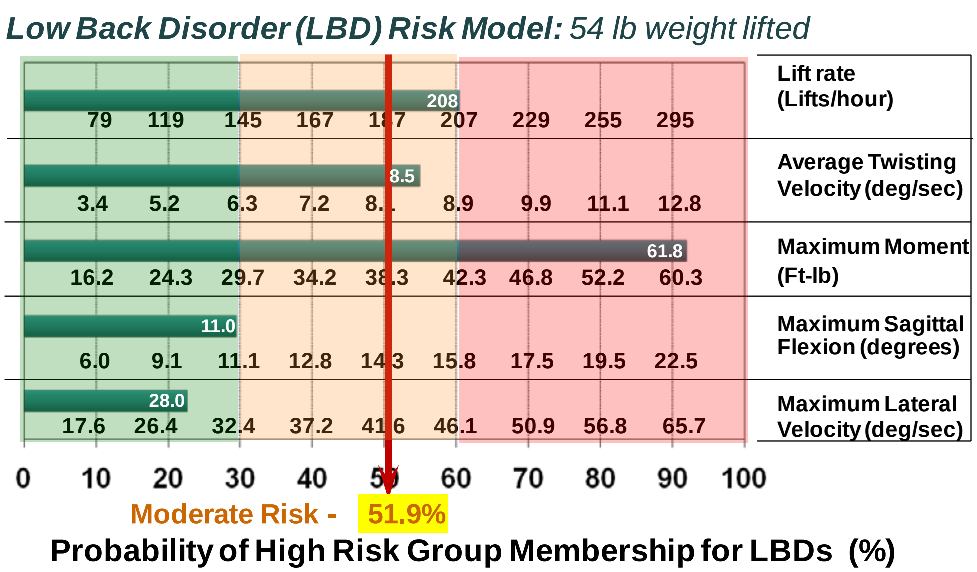


Figure 4.2: POST-Intervention LBD Risk Model Results[2-4]. Lift carton (54 lb) to/from self-leveling cart to/from carry height.

4.3.2 Body Discomfort Results

As shown in Figure 4.3 below, reported Shoulder, Upper Back, Middle Back, Lower Back, and Knee discomfort decreased by **30%**, **45%**, **33%**, **36%**, and **33%**, respectively. No other body parts reported ratings greater than 1.0. Again, it should be noted that the reported discomfort was relatively low both pre- and post-intervention as the discomfort rating scale ranged from 0 to 10.

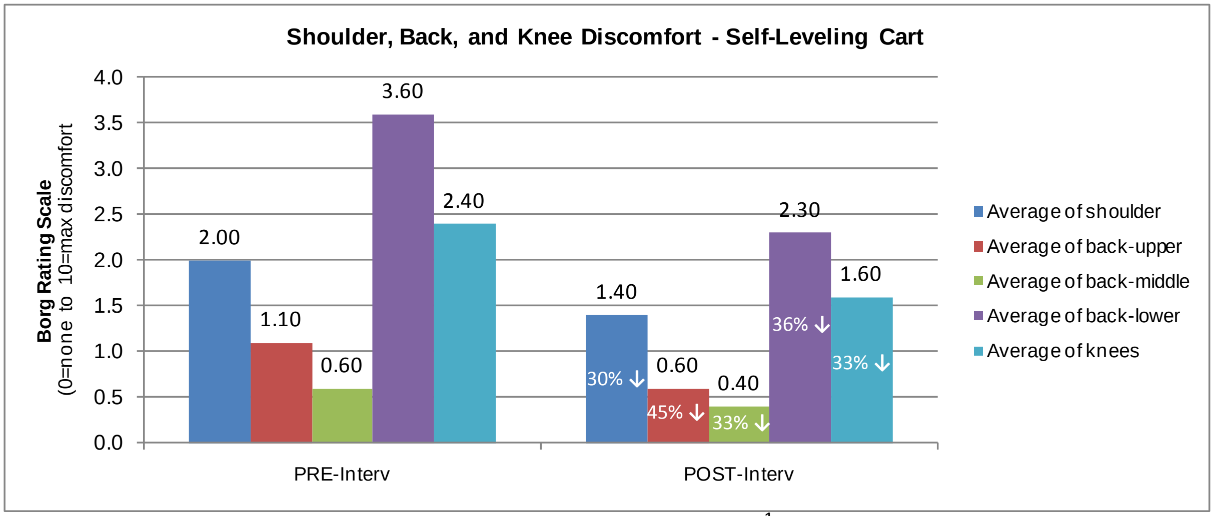


Figure 4.3: PRE- vs. POST-Intervention Discomfort Results[1]**.** Using the self-leveling cart in the back room for pallet breakdown and unload at Deli/Bakery Department storage.

4.3.3 Usability Feedback Results

On-site observations and supervisor follow-ups noted that the self-leveling lift cart was routinely used for Deli/Bakery Department material handling in back room and department storage areas. As shown in Figure 4.4 and Table 4.4 below, the designated Deli/Bakery employee and department manager assigned to department replenishment reported strong positive usability feedback and highly recommended the self-leveling cart.

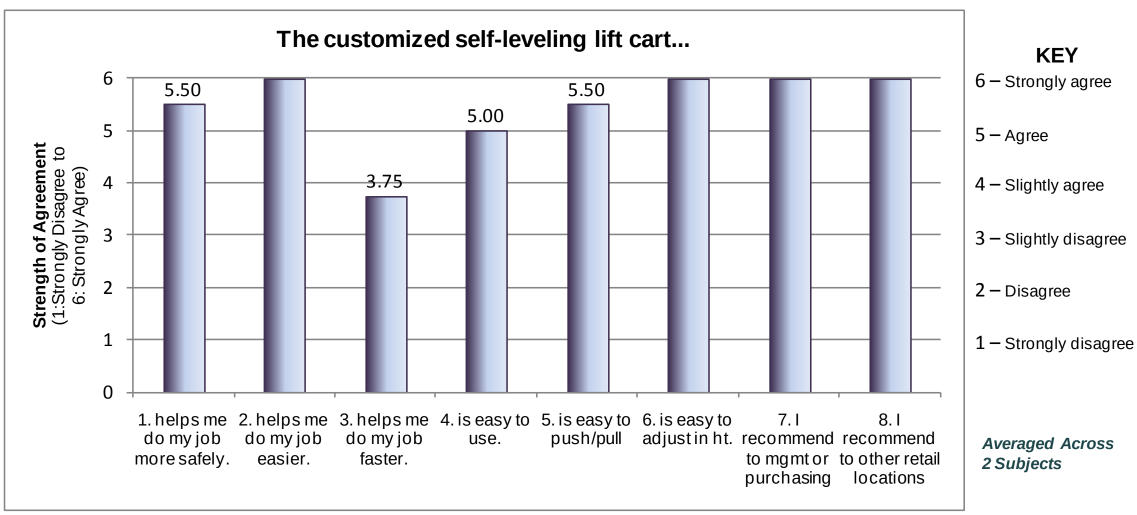


Figure 4.4. Usability feedback on self-leveling lift cart (2 participants).

Table 4.4: Employee comments concerning self-leveling lift cart

Subject ID	Comments / Feedback
S01	I would recommend this modified float, especially for larger stores with bigger trucks & high volumes
S01	It's nice because all lifts [referring to lifts to/from float] are between my waist and shoulder height which I really like
S01	It cuts down on the bending that I have to do by about half
S01	This new float is mine! Nobody better take it from me!
S01	A little extra caution may have to be taken when steering the cart when it's full
S02 (temporary use)	For the top two-thirds of pallet, it made a significant difference in bending [of back]
S02 (temporary use)	Steering of new float was a little different, not dangerous, it just took a little getting used to it…
S02 (temporary use)	Stability of the load seemed fine, I didn't see any issues with that

4.3.4 Productivity Results

Time study data from unloading pallets in back room storage, transporting to Deli/Bakery Department, and unloading in department storage (coolers, freezers) showed a productivity improvement with the use of the self-leveling lift cart. On average, there was a **1.9%** improvement (i.e. **0.44 min. savings**) in Deli/Bakery replenishment time per cart. Assuming an average of twelve Deli/Bakery replenishment deliveries per day, using the self-leveling cart vs. the standard flat-bed cart results in a **5.3 min. savings per day**. Since no time is required to raise / lower the self-leveling lift cart, time savings was purely from reduced bending time to load the bottom half to bottom third of cartons at an elevated position.

4.4 Height Adjustable "High" Lift Cart (Battery Powered) Results

A summary of results from introducing the height adjustable "high" lift cart is highlighted in Table 4.5 below.

Table 4.5: Summary of Results for Height Adjustable Lift Cart	
 **Height Adjustable "High" Lift Cart**	 **PRE-Intervention**  **POST-Intervention**
Intervention Description	• A height adjustable "high" lift cart (battery-powered) was implemented to eliminate the manual carry and allow transport of *multiple cartons* (instead of one at a time) between Deli/Bakery department storage (coolers/freezer) and the meat preparation sink prior to cooking and encourage operators to slide or tip boxes vs. lifting.
Application / Observations	• Used primarily for loading, transporting, and unloading heavy meat cartons (chicken, pork, turkey) weighing greater 14 – 54 lb for meat preparation.
Ergonomics Risk	• Ergo risk ↓ from **HIGH** to **Low** (Back, Shoulders, & Hands/Wrists)[6] for lifts from storage shelves to carry height vs. sliding to height adjustable lift cart for heaviest weights o Compressive force on spine ↓ **41%** from 1,453 lb to 861 lb if 54 lb wt. lifted[6] • Ergo risk reduced from **HIGH** to **Low** (whole body)[7] for carries to prep sink vs. pushing/pulling lift cart • Ergo risk reduced from **Moderate** to **Low** (Arm/Elbow & Hand/Wrist)[6] for one-handed lift of meat bag > 15 lb from carton (resting on sink edge) to prep sink
Body Discomfort	• Reported Low Back discomfort ↓ **29%** (1 associate)
Usability Feedback	• Positive usability feedback and recommended (1 associate)
Productivity	• Productivity ↑ **9.2%** (meat prep time) = **6.2 min savings/day**

4.4.1 Ergonomics Risk Results

A height adjustable “high” lift cart (battery-powered) was implemented to eliminate the manual carry and allow transport of *multiple cartons* (instead of one at a time) between Deli/Bakery department storage (coolers/freezer) and the meat preparation sink prior to cooking and encourage operators to slide or tip boxes vs. lifting. Deli/Bakery personnel used this device primarily for loading, transporting, and unloading heavy meat cartons (chicken, pork, turkey) weighing greater 14 – 54 lb for meat preparation. Ergonomic risk results are summarized for the height adjustable lift cart in Table 4.6 below.

Table 4.6: PRE- vs. POST-Intervention Ergonomic Risk Results (Ht. Adjust. Lift Cart)

Job Task	Analysis Tool Used	PRE-Intervention Results (with standard pallet jack)	POST-Intervention Results (with ht. adjust. lift cart)
Manual two-handed lift from Deli/Bakery Dept. storage (coolers/freezer) shelves	3DSSPP[6] (Back)	**HIGH risk** Low back compressive force = **1,453 lb** Back strength % capable = **64%** (lift weight = 54 lb)	**Low risk** Low back compressive force = **861 lb** Back strength % capable = **96%** (slide force = 15 lb)
	3DSSPP[6] (Shoulders)	**HIGH risk** Shoulder strength % capable = **60%** (lift weight = 54 lb)	**Low risk** Shoulder strength % capable = **97%** (slide force = 15 lb)
	3DSSPP[6] (Hands/Wrist)	**HIGH risk** Hand/wrist strength % capable = **0%** (lift weight = 54 lb)	**Low risk** Hand/wrist strength % capable = **98%** (slide force = 15 lb)
Manual two handed carry from Deli/Bakery Dept. storage (coolers/freezer) to prep sink	LM MMH[7] (whole body - carry)	**HIGH risk** Recommended carry weight limit of 31 lb exceeded (lift weight = 54 lb)	**Low risk** Carry eliminated due to cart use
Manual one-handed lift of meat bag from carton resting on sink edge into sink	3DSSPP[6] (Arm/Elbow, Hand/Wrist)	**Moderate risk** Recommended one-handed lift weight limit of 15 lb exceeded (lift weight = 16-18 lb bag)	**Low risk** Two-handed lift of bag or tipped into sink due to cart use (one-handed lift eliminated)

Ergonomic risk differences were due to the elimination of manual lifting (two-handed or one-handed) or carrying tasks when the height adjustable “high” lift cart was used. Lifting was replaced with sliding and carrying was replaced with pushing/pulling the lift cart, thereby reducing the ergonomic risk to **Low**. Since employees working in department coolers/freezer were exposed to confined spaces and lifts were essentially eliminated post-intervention, the LMM / LBD Risk Model was not used to determine pre- vs. post-intervention ergonomic risk. Therefore, only 3DSSPP and LM MMH tables could be used to assess ergonomic risk differences.

4.4.2 Body Discomfort Results

As shown in Figure 4.5 below, reported Low Back discomfort decreased by **29%** from 1.4 to 1.0. No other body parts reported ratings greater than 1.0. However, it should be noted that the reported discomfort was relatively low both pre- and post-intervention as the discomfort rating scale ranged from 0 to 10.

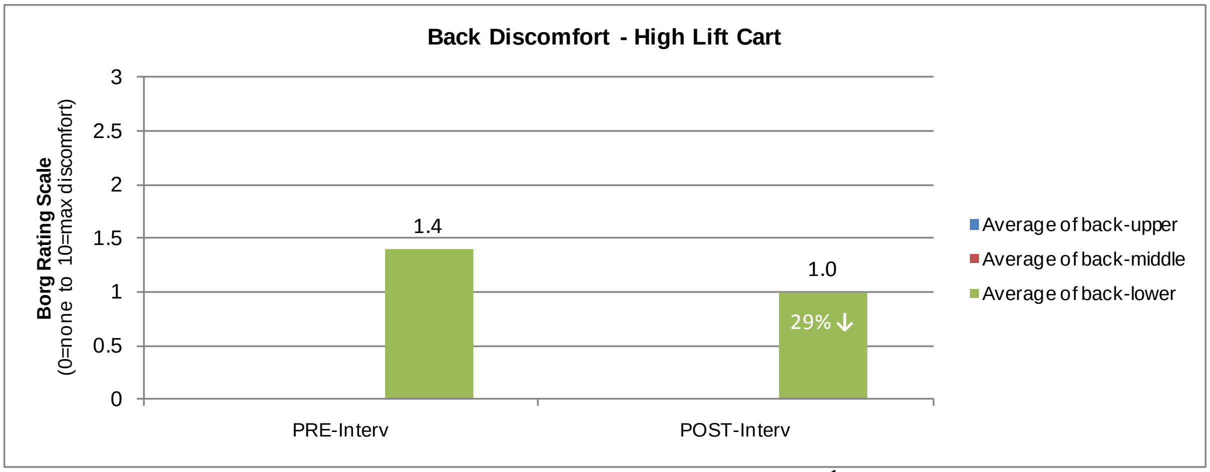


Figure 4.5: PRE- vs. POST-Intervention Back Discomfort Results[1]. Using the height adjustable "high" lift cart in Deli/Bakery Dept. storage to transport and unload at sink prep area.

4.4.3 Usability Feedback Results

On-site observations and supervisor follow-ups noted that the height adjustable "high" lift cart was routinely used for Deli/Bakery Department material handling for the meat preparation process. As shown in Figure 4.6 and Table 4.7 below, the designated Deli/Bakery employee assigned to department meats preparation reported positive usability feedback and recommended the self-leveling cart.

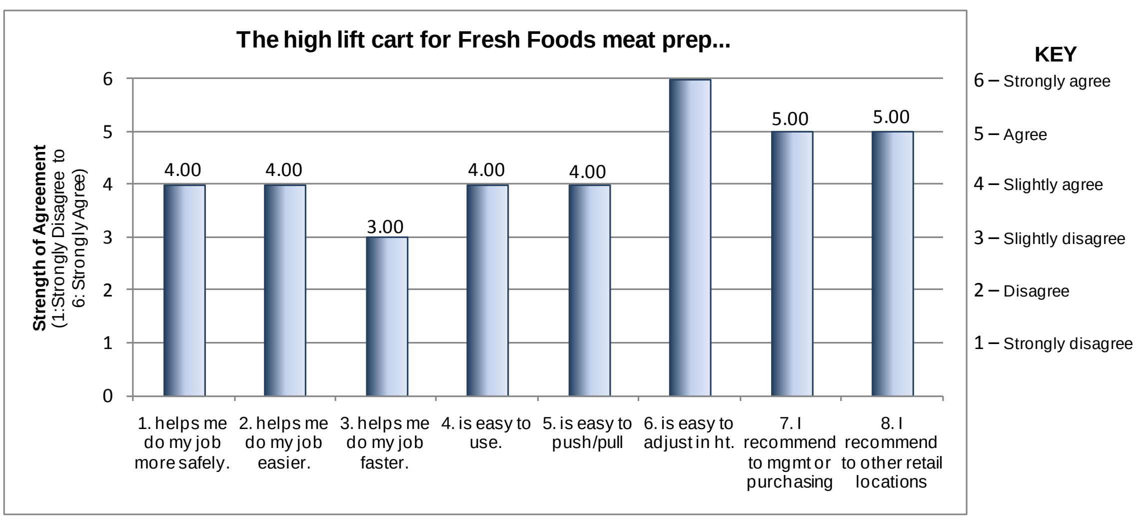


Figure 4.6. Usability feedback on height adjustable "high" lift cart (1 participant).

Table 4.7: Employee comments concerning height adjustable "high" lift cart

Subject ID	Comments / Feedback
S03	It's very easy to adjust in height
	If it [high lift cart] slowed me down a lot, I wouldn't be using it like I am
	When I have the space to move the lift cart in the coolers, I can slide the boxes onto it instead of lifting
	The only issue I see with the lift cart is that it is heavier and a little more difficult to steer & maneuver
	The brake on the lift cart could be a little easier to engage and release

4.4.4 Productivity Results

Time study data from loading, transporting, and unloading *multiple cartons* (instead of one at a time) between Deli/Bakery department storage (coolers/freezer) and the meat preparation sink prior to cooking showed a productivity improvement with the use of the height adjustable "high" lift cart. On average, there was a **9.2%** improvement (i.e. **6.2 min. savings**) in Deli/Bakery meats preparation time per day. Such an improvement resulted from being able to transport multiple cartons to the sink preparation area versus lifting and carrying one carton at a time. The added time to position, raise / lower the lift cart, and slide the cartons onto the cart was also factored into this time savings.

4.5 Equipment Improvement Opportunities

Throughout this pilot demonstration project, there were a few potential improvement opportunities to the equipment introduced that were noted by store personnel, corporate stakeholders, and/or the ergonomics practitioner leading the project. A bulleted list of potential improvements was compiled below:

- ***Both Interventions***
  - Bumpers needed on corners to prevent potential ankle injuries and damage to aisles
  - Guarded or shielded pinch points on scissor lifts

- ***Height Adjustable "High" Lift Cart***
  - Floor lock was difficult to engage and disengage [without steel-toed shoes]
  - Handles could be higher or adjustable

4.6 Return-on-Investment (ROI) Estimates

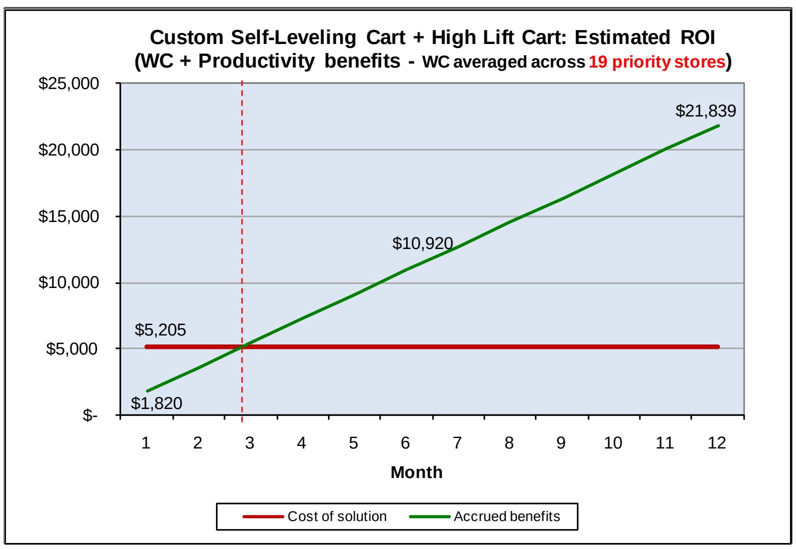
In an effort to determine if the introduction of such material handling interventions may be economically justifiable, potential return-on-investment (ROI) estimations were calculated. Discussing potential roll-out strategies with corporate stakeholders, it was decided that the two interventions introduced in this project would provide a better ROI if rolled out among stores with higher incidence of strains/sprains related to material handling among Deli/Bakery personnel. Therefore, workers compensation data over 2009-2010 was analyzed to identify "***high priority***" stores that had two or more strain/sprain incidents per year among Deli/Bakery personnel related to material handling. Nineteen (19) total stores were identified as "***high priority***" among all stores company-wide.

As shown in Figure 4.7, the "Total first-year cost of control" included equipment costs of purchasing one of each of the custom self-leveling lift cart and the height adjustable (battery) "high" lift cart as well as estimated shipping, training and maintenance costs. An annual recurring cost of $200 was also included in this ROI forecasting.

Estimated annual benefits included an estimated **40%** reduction in direct and indirect costs associated with workers compensation claims. The 40% reduction was considered a conservative estimate based on a number of intervention case studies that reduced the level of physical exposure to an ergonomic hazard, such as by introducing load-leveling devices as done in this study (Puget Sound Human Factors Society - http://www.pshfes.org/cba.htm). Direct costs of strain/sprain claims among Deli/Bakery personnel were taken from company workers compensation data and averaged across the 19 "***high priority***" stores to give average direct costs at one store location. Indirect costs were estimated from the OSHA e-tool as a function of direct claims cost as shown below (http://www.osha.gov/SLTC/etools/safetyhealth/images/safpay1.gif):

- Less expensive claims have proportionally higher ***indirect costs***:
  - WC claim ≤ $2,999 = 4.5 x claim cost in indirect costs
  - WC claim $3,000 – $4,999 = 1.6 x claim cost in indirect costs
  - WC claim $5,000 – $9,999 = 1.2 x claim cost in indirect costs
  - WC claim ≥ $10,000 = 1.1 x claim cost

Lastly, productivity improvement was also included as a benefit in the ROI calculation. Total annual time savings for introducing both devices was converted into a potential labor cost savings or time savings that could be spent doing other job functions. An average labor cost of $15/hour was assumed. The estimated annual productivity improvement savings from introducing the custom self-leveling cart and height adjustable "high" lift cart was **$494** and **$566** per store, respectively, for a total savings of **$1,060**.



Total first-year cost of control:	$ 5,205.00
Annual recurring costs:	$ 200.00
Estimated annual benefits:	$ 21,839.00
Estimated payback period:	0.24 year (2.9 months)
Estimated net benefits after 1 year:	$ 16,634.00
Estimated net benefits after 3 years:	$ 59,913.00
Estimated net benefits after 5 years:	$103,192.00

Self-Level Cart + High Lift Cart	
Reduction in claims:	40%
Reduction in WC costs:	$ 9,530.00
Reduction in indirect costs:	$ 11,249.00
Increase in productivity:	$ 1,060.00

Figure 4.7. Estimated ROI results shown above are for one store location only, in which interventions are introduced. WC data averaged across "**high priority**" stores *(i.e. ≥ 2 sprain/strain Deli/Bakery Dept. incidents per year).* There were 19 total stores between 2009 & 2010 FY.

As shown in Figure 4.7, the estimated payback period after introducing both interventions in a single "**high priority**" store, was **2.9 months**. Estimated net benefits after one year, three years, and 5 years of introduction was **$16,634**, **$59,913**, and **$103,192**, respectively, at a single store. These estimates certainly support the notion that the two interventions may prove to be economically justifiable. However, additional studies are recommended to verify such estimates.

4.7 Limitations of Project

This project served as a pilot study with a limited number of participants, equipment applications, and over a relatively short period of time (6-week trial period). Therefore, it cannot be said that results showed statistically significant differences with adequate statistical power. Constraints that limited participant involvement and data collection across multiple store personnel included: (1) minimizing process disruption and productivity demands and (2) specific store employees were assigned to specific tasks and product types, thus we were limited on the number of experienced personnel to collect accurate pre- vs. post-intervention data. Future studies are recommended across more participants and more superstores.

5. Conclusions

In summary, pilot results from this study certainly show promise that such “load-elevating” equipment may have both ergonomic and productivity benefits in the retail trade sector. Both interventions trialed in this demonstration project showed a reduction in ergonomic risk level, a reduction in reported discomfort, improved productivity, and reported positive usability feedback by store employees. Such findings lend support that manual material handling improvements are possible and may prove beneficial in retail environments that have not changed in decades.

Disclaimer: It should be noted that The Ergonomics Center of North Carolina served as an unbiased entity of North Carolina State University throughout this project. It is not our intention to recommend or endorse a particular equipment manufacturer, vendor, or specific product. Services rendered were purely for evaluation purposes and future testing and/or intervention implementation is at the discretion of the host company.

6. References

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APPENDIX A: Usability and Discomfort Survey

Usability Questionnaire

Subject ID:
Date:

Please rate the following statements on a scale of 1-6 where your rating indicates your agreement with the statement.

1. Strongly disagree
2. Disagree
3. Slightly disagree
4. Slightly agree
5. Agree
6. Strongly agree

Baseline and During Shift

The new MMH equipment used in my job…	
1. helps me do my job more safely.	
2. helps me do my job easier.	
3. helps me do my job faster.	
4. is easy to use.	
5. record **Comments** below.	

After Shift is Completed

1. The implemented MMH assist equipment was easy to push/pull _____
2. The implemented MMH assist equipment was easy to adjust in height _____
3. I would recommend this MMH assist equipment to my management or purchasing agent _____
4. I would recommend this MMH equipment to other retail locations performing similar tasks _____
5. **Comments** about MMH assist equipment (Use **Back** of page if needed)

____
____
____
____
____
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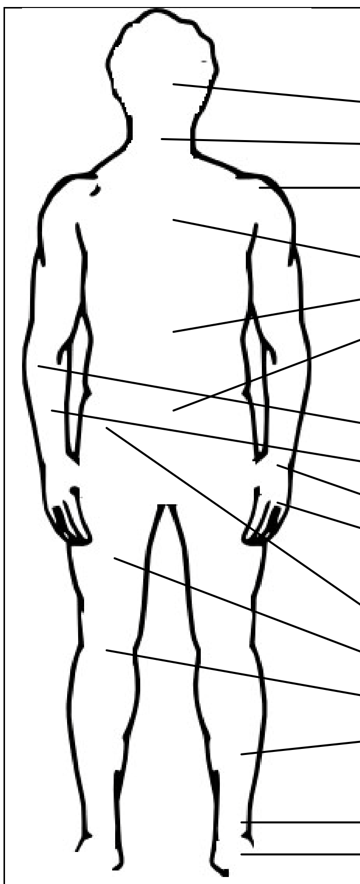
____
____

Discomfort Data (Pre- & Post-Intervention)

Please rate the level of **discomfort** in each area of your body using the Borg scale below.

Subject ID:
Date:

Rating	Description
0	No discomfort at all
0.3	
0.5	Just noticeable discomfort
0.7	
1	Very little discomfort
1.5	
2	Light discomfort
2.5	
3	Moderate discomfort
4	
5	Strong discomfort
6	
7	Very strong discomfort
8	
9	
10	Extremely strong (“Maximal”)
*	Absolute Maximal



		+0 h	+2 h	+4 h	+6 h	+8 h
	Whole body					
	Head					
	Neck					
	Shoulder					
	Back - upper					
	Back - middle					
	Back - lower					
	Elbows					
	Forearms					
	Wrists					
	Hands					
	Hips					
	Upper legs					
	Knees					
	Lower legs					
	Ankles					
	Feets					