OSC | 11
Ohio Safety Congress & Expo

#175 – Distribution center ergonomics: Assessing back injury risk and developing interventions

William Marras, CPE, Steve Lavender, CPE and Carolyn Sommerich

Thursday, March 31, 2011
2:30 to 3:30 p.m.

Ohio | Bureau of Workers' Compensation

Distribution Center Ergonomics: Assessing Back Injury Risk and Developing Interventions

Presented by:

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Background

- Epidemiologic Link between physical work demands and occupational LBP (NIOSH 1997, Punnett, 1991, Waters, 1999; NRC, 2001, Andersson, 1991; Marras et al., 1993; Marras et al. 2010)
- In the U.S. in 2007 the Transportation and Warehousing sector had one of the highest incidence rates for back pain (84.2 /10,000 hrs)
- As manufacturing has shifted out of the US the proportion of the workers working in distribution centers has increased.

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From an Ergonomics Perspective: Distribution centers present workers with challenging MMH tasks – Repetitive lifting where the objects vary in weight, size, and their physical location

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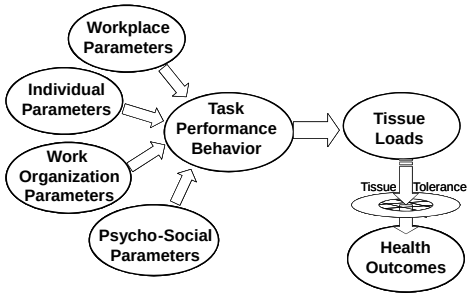
Injury Development Model



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Injury Risk Study Objective

- Quantify dynamic physical work load characteristics and assess relationship with change in back function (risk)

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Methods

Research Question - What components of work exposure are associated with a decrement in spine function over time?

Study Features

- Prospective field study in Distribution Centers
- Quantitatively assess spine function changes
- Quantify various dimensions of risk factor exposure at worksite
- Jobs are unit of analysis
- Multivariate analysis

Prospective Study Design

Baseline — **Follow-up** (after 6 mo.) — **Time**

Health Effects Measurements
(all workers on job)
- Background
- Health History
- Questionnaire
  - Health
  - Psychosocial
  - Perception
- Kinematic Back Function

Work Exposure Measurements
(subset of workers (3-7) from each job)
- 390 continuous measurements per lift monitored over ½ day

Health Effects Measurements
(all workers on job)
- Health Questionnaire
  - Health
  - Psychosocial
  - Perception
- Kinematic Back Function

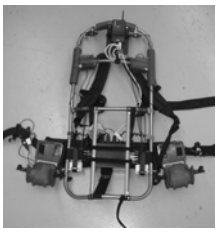
Spine Functional Assessment:

Compares spine kinematics to normative database to assess degree of functional impairment p(n)
(sensitivity: 90% / specificity: 92%)

(Marras et al. 1993; 1995; 1999; 2000; Ferguson and Marras, 2004; 2009)

Exposure Assessment:

Laboratory in a backpack (3.4 kg)
390 measures recorded continuously



Categories of Measures
- Load weight, force, acceleration, etc.
- Load direction (lift, push, pull, etc.)
- Load 3-D path and motion (position, velocity, and acceleration)
- Trunk position, velocity, and acceleration
- Timing (cycle times, peak loads, cumulative measures, etc.)

(Marras et al., 2009)

Exposure Assessment:
Force Measurement

Directional Force, acceleration, etc. to derive static/dynamic load moments, push/pull force, etc.

- Accuracy: +/- 0.5 Kg

(Marras et al., 2009)

Dynamic Exposure Measurements:

Position and Movement of loads and Spine

Measurement Categories
- 3D Position, distances, velocity, acceleration, heights, reaches
- Timing, frequency, cumulative loading

- **Accuracy**: position AAE = 3.8 cm; motion R^2 = .98

(Marras et al., 2009)

Measuring Load Moments in different DCs

Data Acquisition System

Continuous Recording of 390 variables:

- 3-D Positions
- Trunk Kinematics
- Load Characteristics
- Timing Features

Definition of Job Risk for Low Back Impairment

High Risk Jobs

- Worker must have significant decrease in spine function [at least 0.14 change in p(n)] over prospective period (Ferguson et al. 2009)
- At least 30% of workers on the job had a significant decrease in p(n)

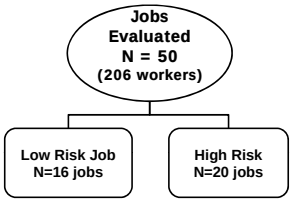
Low Risk Jobs

- Workers had no or positive change spine function [p(n)]

Jobs Eliminated from Consideration

- Change in function decrement was moderate [p(n) between 0 and 0.14]

Workplace Exposure Assessment

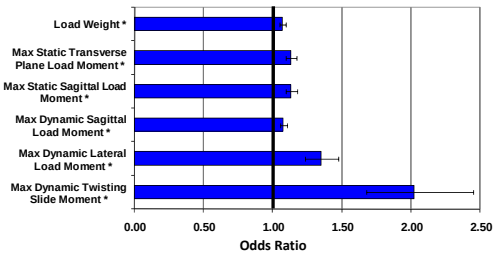


- Work Exposure database = 60,000 lifts x 390 measures
- **High Risk Job = Greater than 30% of workers in job exhibiting a meaningful decrease in spine function**

(Ferguson et al., 2009)

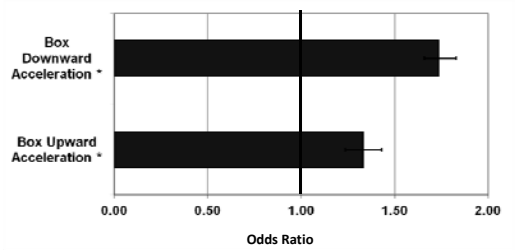
Risk Model Results

Load (Force): Univariate (continuous) Odds Ratios (with 95% Confidence Intervals)



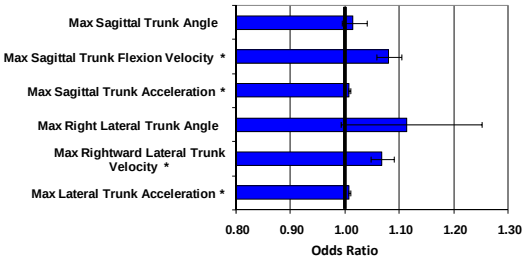
*** Statistically significant**

Load Acceleration: Univariate (continuous) Odds Ratios (with 95% Confidence Intervals)



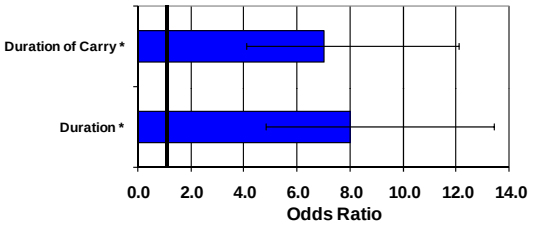
* statistical significance

Spine Kinematics: Univariate (continuous) Odds Ratios (95% Confidence Interval)



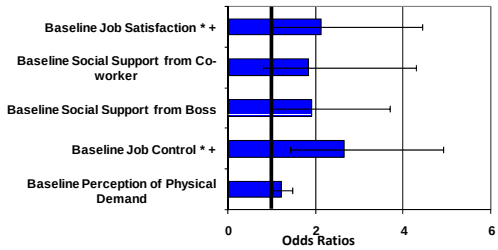
* statistical significant

Temporal Measures: Univariate (continuous) Odds Ratios (95% Confidence Intervals)



* statistical significance

Psychosocial and Perceived Physical Demand: (continuous) Univariate Odds Ratios (95% Confidence Intervals)



* Statistical significance

+ predicts low risk (protective)

Multivariate Model Predicting Significant Decrease in Spine Function

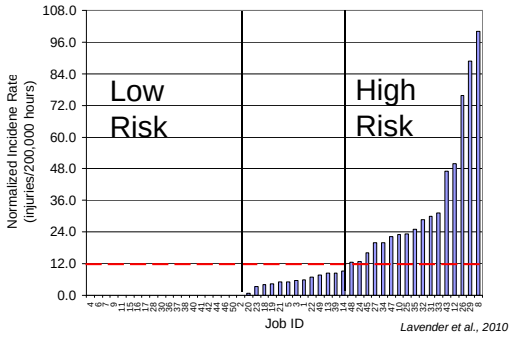
Variables	Cut-Point	Beta	Odds Ratio	Confidence Interval
Lateral Trunk Velocity (Rt.)	>84.1 º/s	3.559	35.14	14.1-87.7
Timing (%) of Max Dynamic Asymmetric Load Moment	>47.6 %	3.252	25.84	8.5-78.2
Dynamic Resultant Sagittal Bending Moment	> 49 Nm	1.623	5.07	1.86-13.8

Model Performance

Sensitivity = 85%
Specificity = 87.5%

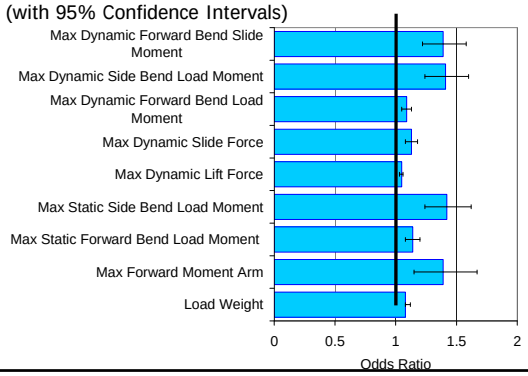
Positive predictive value = 89.5%
Negative predictive value = 82.4%

OSHA Recordable Back Injury Rates



Lavender et al., 2010

OSHA Recordables: Force & Moment Results - Univariate Odds Ratios
(with 95% Confidence Intervals)



OSHA Recordables: Multivariate Model Predicting Risk Group Membership

Variable	Threshold	P-Values	Odds Ratio
The average of the job's peak dynamic forward load moments (Nm)	> 43.9	0.0001	10.2
The average of the maximum dynamic slide forces (N)	> 38.9	0.0001	17.1
The average duration of the non-load exposure period (seconds)	< 24.2	0.054	2.5

Model Performance

Sensitivity = 86.7%
Specificity = 73.3%

Discussion

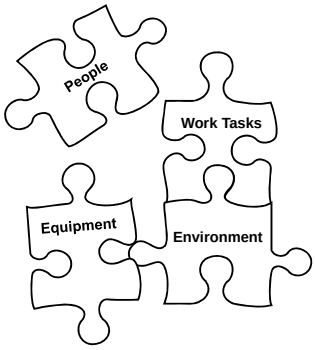
- Developed very sensitive and specific model that predicts risk of low back function impairment
- Impairment measure related to back pain (Marras et al, 1999)
- Dynamic characteristics are important for risk identification
  - Importance of dynamic variables vs. posture
- Interactive nature of variables
  - Dynamic resultant load moment - includes pushing and pulling as well as lifting
  - Lateral trunk velocity
  - Timing of peak load - suggests eccentric loading is important

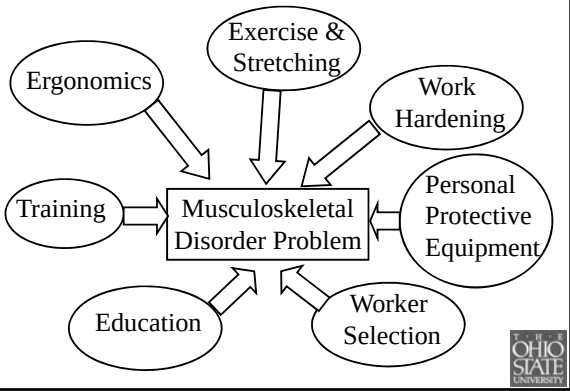
Discussion (continued)

- Multivariate model variables have generally linear relationship with risk
  - But are important breakpoints that dictate risk
- Similar model describes LBP reporting in these facilities
- Model consistent with previous LMM risk model
  - Dynamic trunk motion is important for identifying risk (Marras et al., 1993; 1995)

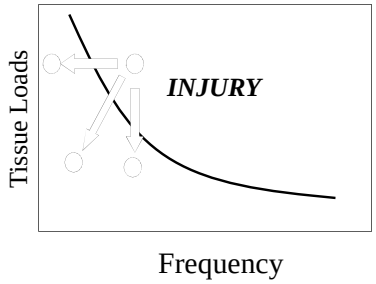
Intervention Process

Ergonomics





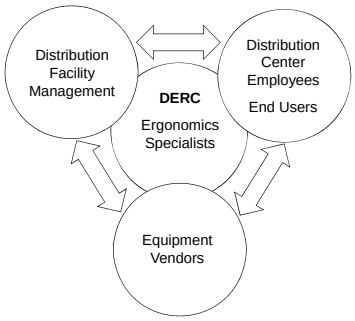
Managing Load Exposure

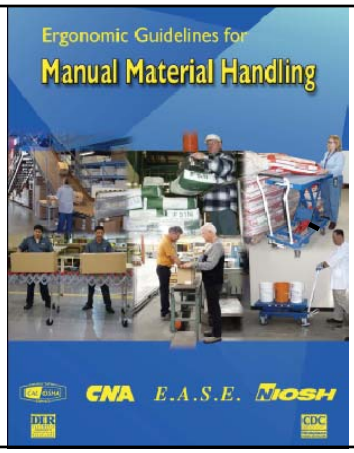


Distribution Ergonomics Research Center

- Mission
  - To identify, develop, and evaluate ergonomic interventions (methods, tools, equipment, processes, etc.) that will allow distribution center workers to work more efficiently and safely.

OSU Distribution Ergonomics Research Center Participatory Process





Approach – Engaging the users

Stakeholder Partners

Focus Group with **Grocery** Distributors

Focus Group with **Apparel** Distributors

Focus Group with **General Merchandise** Distributors

Distribution Ergonomics Research Center Supply Chain Solutions

Identify Focus Group Participants
↓
End User Input
↓

Grocery: Physically Challenging Items

- meats
- juice
- canned food
- potatoes / onions
- detergents
- water
- dog food
- pop
- bleach

Distribution Ergonomics Research Center Supply Chain Solutions

Identify Focus Group Participants
↓
End User Input
↓
Needs Identification and Prioritization
↓

Approach: Identifying existing best practices

- **Raising material off the floor using empty pallets**

Approach: Identifying existing best practices

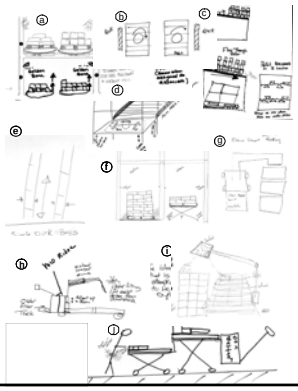
- Raising material off the floor using empty pallets
- **Providing access to heavier and or bulkier items**

Approach: Identifying existing best practices

- Raising material off the floor using empty pallets
- Providing access to heavier and or bulkier items
- **Turning pallets to provide access**

Approach: Brainstorming Process

Identify Focus Group Participants
↓
End User Input
↓
Needs Identification and Prioritization
↓
Brainstorming: Sketching Exercise



Approach: Brainstorming Process

Identify Focus Group Participants
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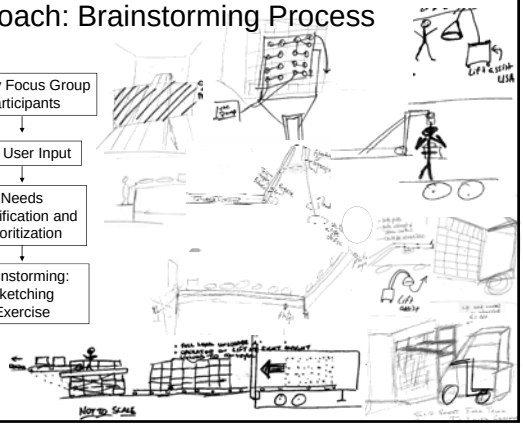

Approach: Brainstorming Process

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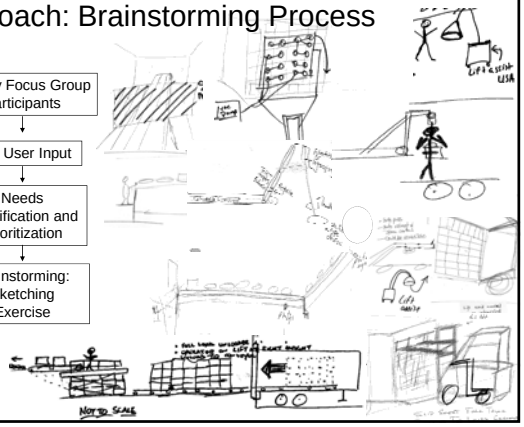

Approach: Brainstorming Process

Identify Focus Group Participants
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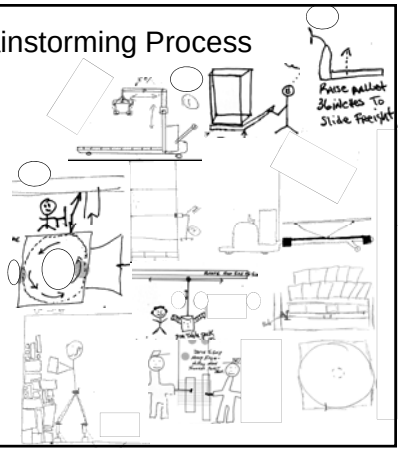
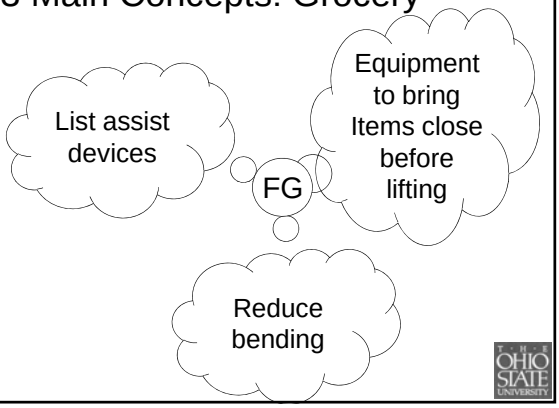
Brainstorming: Sketching Exercise



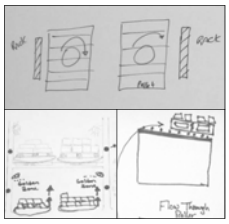
3 Main Concepts: Grocery

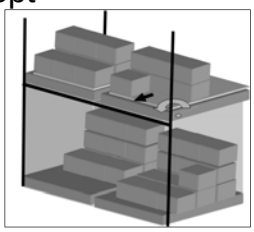


Approach: Concept Development

Identify Focus Group Participants
↓
End User Input
↓
Needs Identification and Prioritization
↓
Brainstorming: Sketching Exercise
↓
Refined Concepts
↓
Identify Existing or Potential Vendors
↓
Obtain Participant Feedback Via Survey
↓
Obtain End User Feedback
↓

Flow Pallet Concept





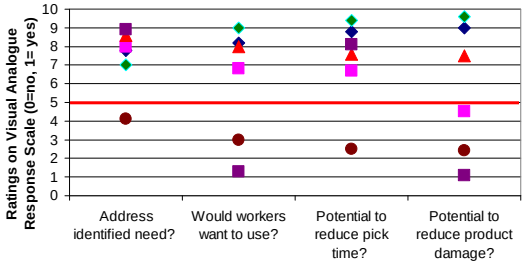
Identified Need/ Goal / Purpose

- Reduce reach distance into racks.

Concept Description: A specialized pallet for use in 2-tier pick racks that contains a conveyor mechanism to shift product forward.

Status: Concept is being developed by Hamilton Caster.

Flow Pallet: Focus Group Participant Feedback via Survey



Comments and Concerns: Impact on overall system productivity – returning flow pallets to the dock

What do end users think?

- Conducted 8 sessions with 41 hourly employees at 2 Grocery Distribution Centers
- Asked to rate concepts on:
  - Usability
  - Usefulness
  - Desirability

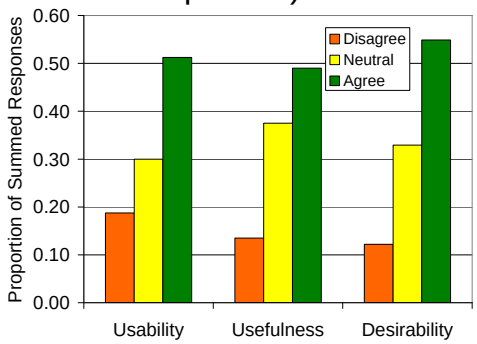
Usefulness

Usefulness	SD	D	N	A	SA
1. I think this flow pallet can **reduce the picking time**.	5	1	17	11	6
2. I believe that this flow pallet could **make my work easier**.	3	1	12	16	8
3. I believe this flow pallet will help me perform my selection tasks more **efficiently**.	5	1	13	15	6
4. I believe this flow pallet will allow me to be **less tired** at the end of each work day.	3	2	20	10	5
5. I believe this flow pallet has the potential to **reduce product damage**.	3	3	13	13	8

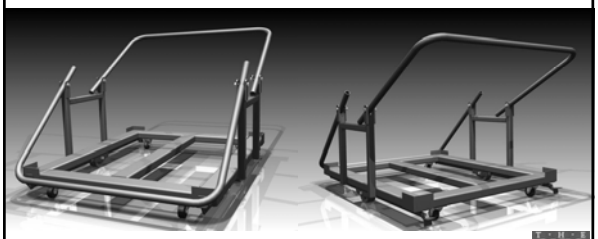
Desirability

Desirability	SD	D	N	A	SA
1. **I would really benefit** from the use of this flow pallet.	4	3	19	9	6
2. I would **like to try** this flow pallet.	3	1	10	18	9
3. I think some of **my co-workers would want** to use this flow pallet.	3	2	9	22	5
4. **I would like to see** us obtaining products in 2nd tier slots using this flow pallet.	3	1	16	12	9

Flow Pallet: Employee Feedback (Summed Responses)

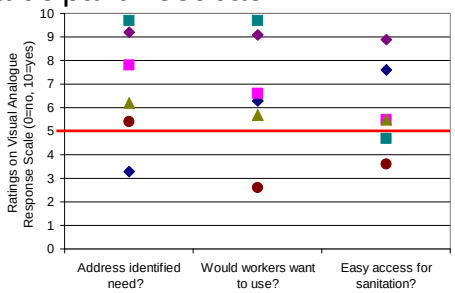


Pallet Cart Concept



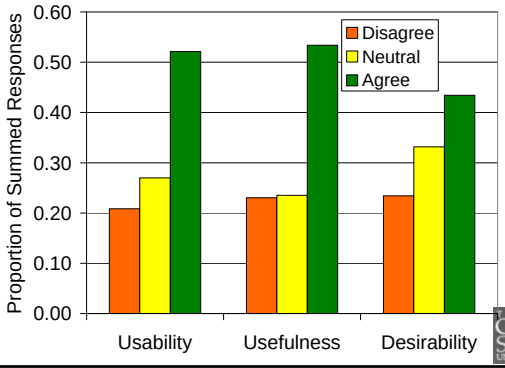
Drawings courtesy of Hamilton Caster

Pallet Cart- Focus Group Participant Feedback



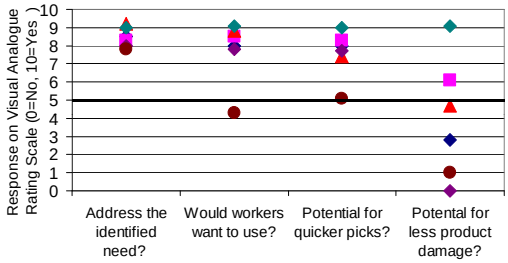
Comments and Concerns: Still have push pull issues, time to turn, reduces training required for sanitation function.

Pallet Cart – Employee Feedback



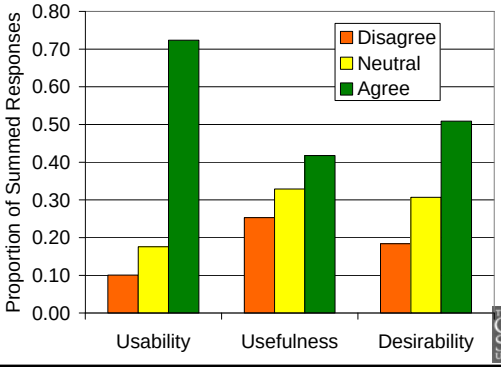
Pick hooks

Pick Hooks – Focus Group Participant Feedback

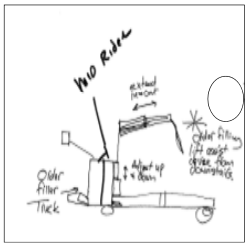


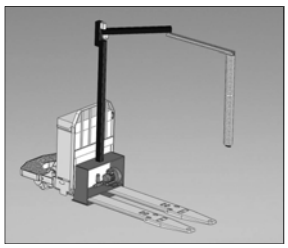
Comments and Concerns: Durability, slippage, challenging to have employees use

Pick Hooks- Employee Feedback



Pallet Jack Mounted Lift Assist



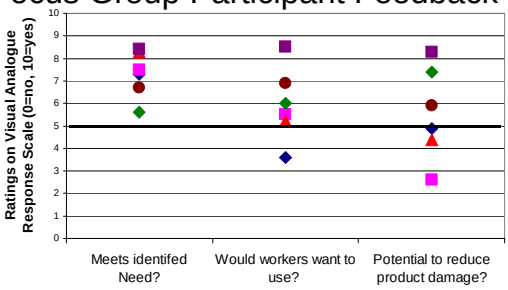


Drawing courtesy of Gorbel, Inc.

Eco Pick- Pallet Jack Mounted Lift Assist

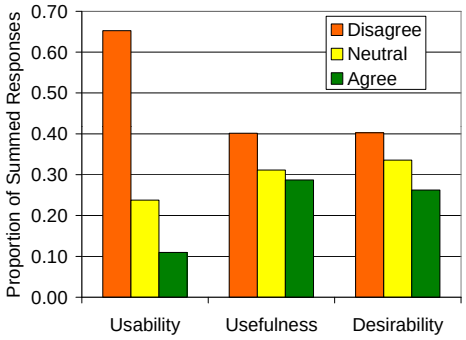
Pallet jack mounted lift assist

Pallet Jack Mounted Lift Assist- Focus Group Participant Feedback

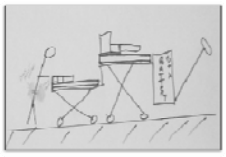


Concerns: Productivity, Overall height, Would it work with existing racks

Pallet Jack Mounted Lift Assist- Employee Feedback



Elevated Pallet Jacks for Product Selection



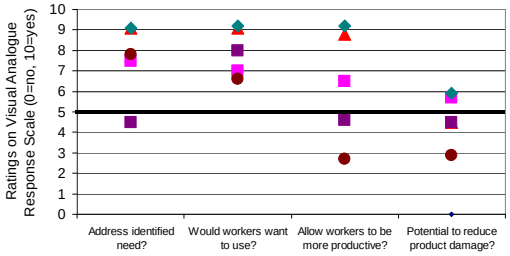
Identified Needs/ Goals / Purpose

- Reduce bending when loading pallets.
- Independently adjustable as pallets are built at different rates.

Concept Description: Double pallet jack that can raise forks to waist level.

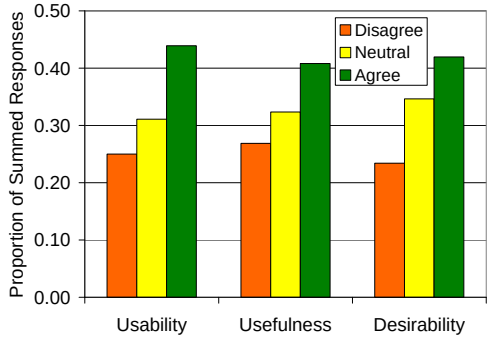
Status: Atlet USA, though not widely used within the US as it requires open bottomed pallets.

Elevated Pallet Jack – Participant Feedback

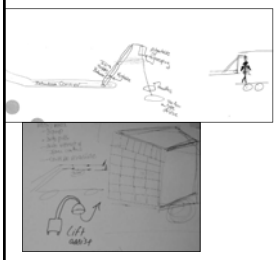


Comments and Concerns: Needs pallets without bottoms, front riding vs. mid rider positioning, stability of load.

Elevated Pallet Jack- Employee Feedback



Lift Assist for Trailer Unloading



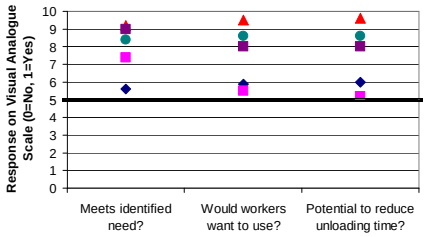
Identified Need / Goal / Purpose: Reduce physical demands on workers when unloading trailers.

Equipment Description: A lift assist used when loading or unloading heavy items in trailers and containers. It can either be configured as a stand alone device or can be attached to an extendable conveyor.

Status: Vaculex Parcel Lift exists.

Vaculex Parcel Lift

Lift Assist for Trailer/Container Unloading-Participant Feedback



Articulating Belt Extension (Container De-Stuffer)

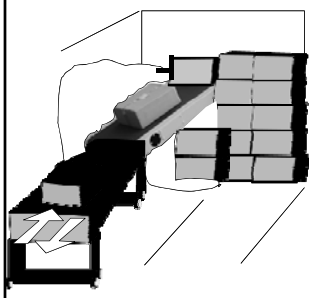
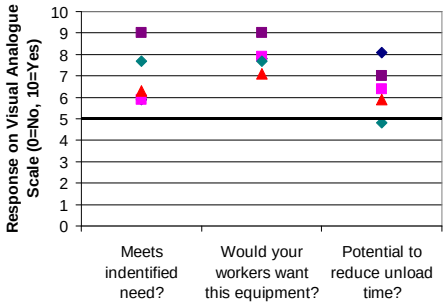
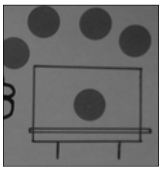


Photo Courtesy of Engineered Lifting Systems & Equipment Inc.

Articulating Belt Extension- Participant Feedback



Layer Pick for Pallet Breakdown

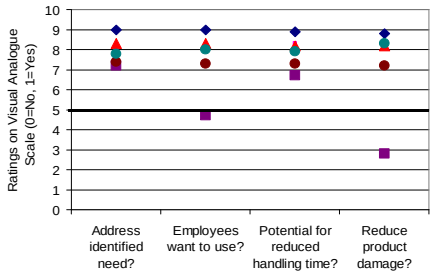


Identified Need/ Goal / Purpose: A large blade in place of forks to split layers of mixed product off a received pallet.

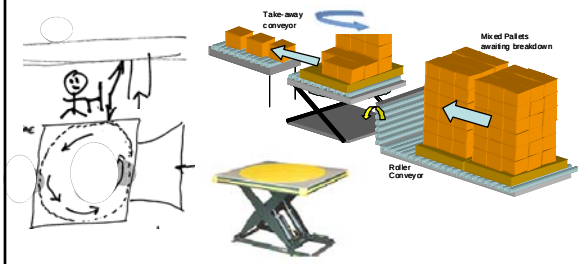
Equipment Description: The Froglift is an attachment that can be applied to forklifts which can remove one layer of product at a time.

Status: Existing products may work – froglifttlayerpicker.com

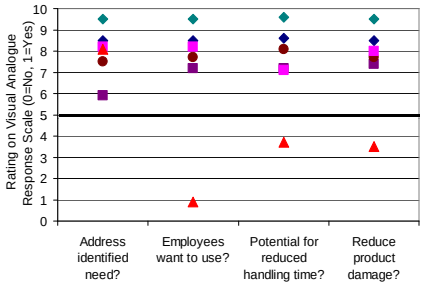
Layer Pick for Pallet Breakdown



Pallet Breakdown Station



Pallet Breakdown Station



Summary

- Organizations employing "best practices" have the potential to reduce exposure to MSD risk factors.
- Through a participatory process several opportunities have been identified to reduce musculoskeletal demands during product selection.
- Validation and usability studies still need to be conducted on many of these intervention concepts.

Thank You for your interest!

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