Digital Human Modeling of Non-Occupational Risk Factors for Manufacturing Work Task Design

1st International Symposium to Advance TOTAL WORKER HEALTH

Bethesda, MD, October 6-8, 2014

Presented by:

Mark Schall, MS, AEP

The University of Iowa
College of Public Health

Healthier Workforce
Center for Excellence

Comprehensive Evaluation of an Integrated Health Protection and Health Promotion Program

Four-year intervention trial (2012-2016)

Two facilities operated by same manufacturing company

Does an integrated approach:

1. Reduce occurrence and impact of musculoskeletal health outcomes?
2. Reduce modifiable risk factors for chronic health conditions?
3. Provide an economic benefit?

Project Team

Nathan Fethke, PhD	(PI)
Fred Gerr, MD	(Co-I)
Linda Merlino, MS	(Study Coordinator)
Cassidy Branch, MA	(Wellness Coach)
Mark Schall, MS	(Graduate Fellow)

HEALTHIER WORKFORCE CENTER FOR EXCELLENCE

www.hwce.org

Program Design

Background and Significance

Work-related musculoskeletal disorders (MSDs) are prevalent among manufacturing workers Gerr et al., (2014)

Risk factors associated with the development of MSDs

- Physical risk factors (e.g., repetition, forceful exertions)
- Psychosocial risk factors (e.g., high job demands / low job control)
- Workplace organizational factors (e.g., no job rotation)
- Non-occupational risk factors (e.g., age, gender, body mass index)

Background and Significance

Manufacturing safety committees are commonly tasked with

- Identifying potential occupational risk factors
- Modifying work tasks to reduce exposure

Methods used to assess the ergonomics of work tasks do not typically consider non-occupational risk factors

Example: Strain Index

- Rating system to estimate risk for upper extremity MSDs
- Observer assesses six work-related variables
  - Intensity of exertion
  - Speed of work
  - Hand exertions per minute
  - Hand and wrist posture
  - Duration of exertion (i.e., duty cycle)
  - Duration per day work is performed

Does <u>not</u> consider non-occupational risk factors!

Digital Human Modeling

SANTOSHUMAN®

VIRTUAL SOLDIER RESEARCH

http://www.ccad.uiowa.edu/vsr/

SIEMENS

http://blog.industrysoftware.automation.siemens.com/blog/2009/03/19/are-digital-humans-cool/

ANYBODY™ TECHNOLOGY

http://biomechanicsforeverybody.wordpress.com/category/modeling/

- Evaluate the ergonomics of existing work tasks
- Develop and evaluate alternative designs
- Consider non-occupational risk factors in work task design

HEALTHIER WORKFORCE CENTER FOR EXCELLENCE

www.hwce.org

Santos Digital Human

Biomechanical, computer-based model that predicts static posture, dynamic motion, joint strength and fatigue

Human performance capabilities based on research conducted by University of Iowa Virtual Soldier Research program

Initially developed for military applications

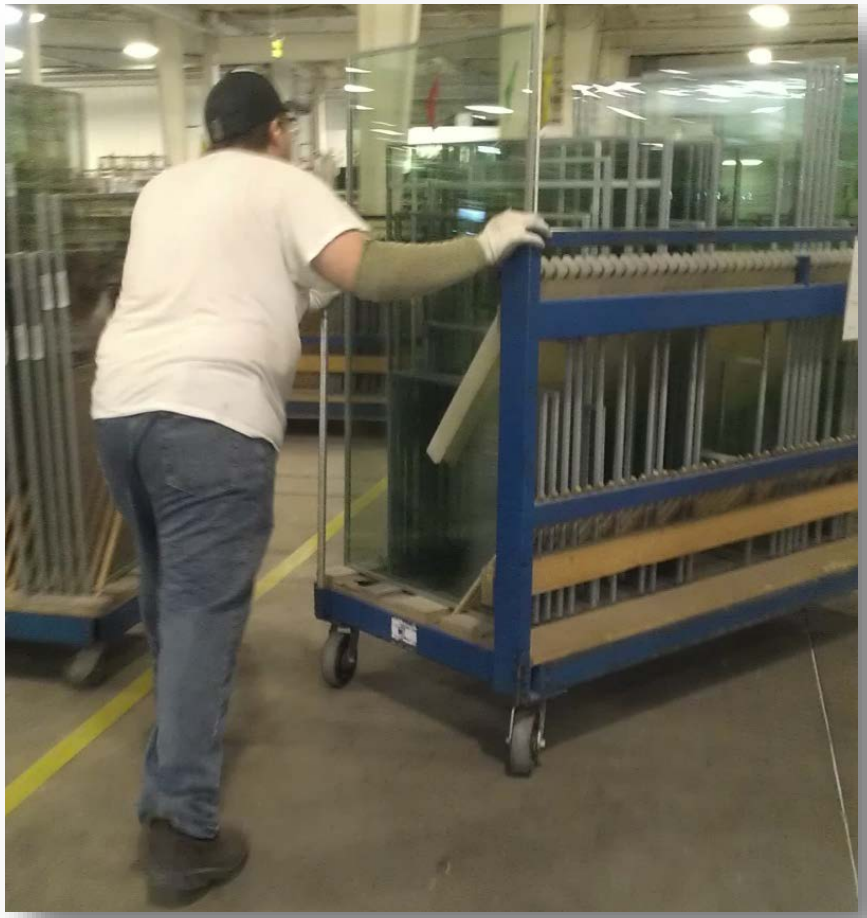
http://www.ccad.uiowa.edu/vsr/

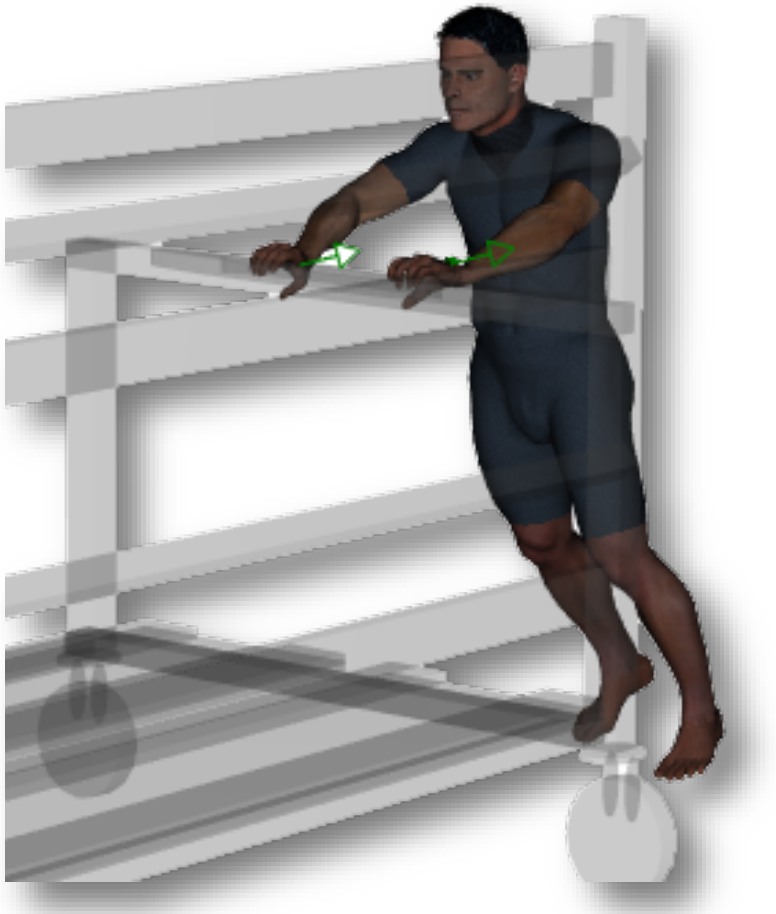
SANTOSHUMAN®

HEALTHIER WORKFORCE CENTER FOR EXCELLENCE

www.hwce.org

Evaluate Existing Work Tasks





HEALTHIER WORKFORCE
CENTER FOR EXCELLENCE

www.hwce.org

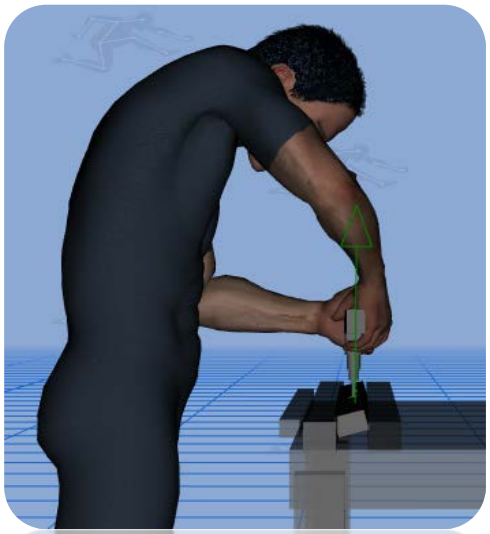
Develop and Evaluate Alternative Work Stations

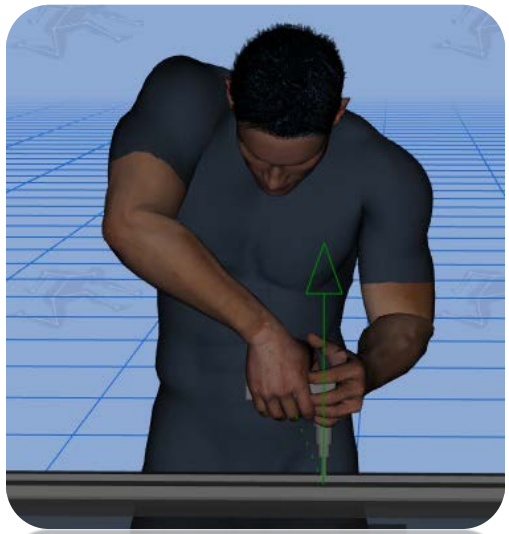
HEALTHIER WORKFORCE CENTER FOR EXCELLENCE

www.hwce.org

Develop and Evaluate Alternative Work Stations

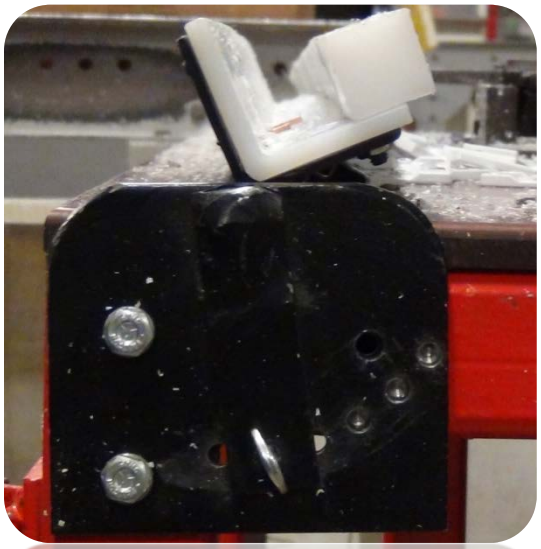
Original - 90° from horizontal drilling

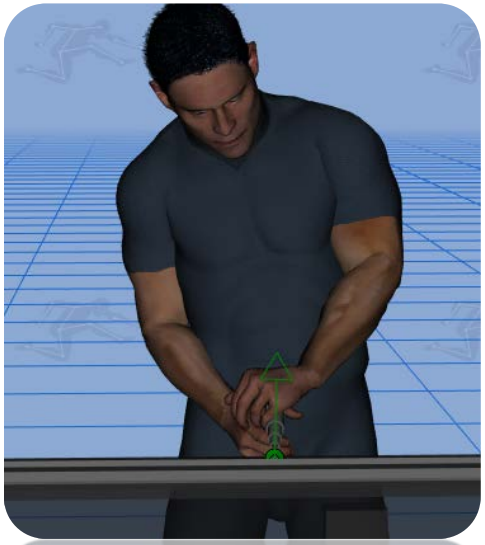




Develop and Evaluate Alternative Work Stations

Alternative – Adjustable drilling position





HEALTHIER WORKFORCE CENTER FOR EXCELLENCE

www.hwce.org

Consider Non-Occupational Risk Factors

Example: Evaluate effect of BMI on work task design criteria

Healthy BMI Model:
BMI = 19.1 kg/m^2

Strength and mobility profile based on empirical data of 100 healthy BMI individuals

Overweight BMI Model:
BMI = 31.1 kg/m^2

Strength and mobility profile based on empirical data of 100 overweight BMI individuals

HEALTHIER WORKFORCE CENTER FOR EXCELLENCE

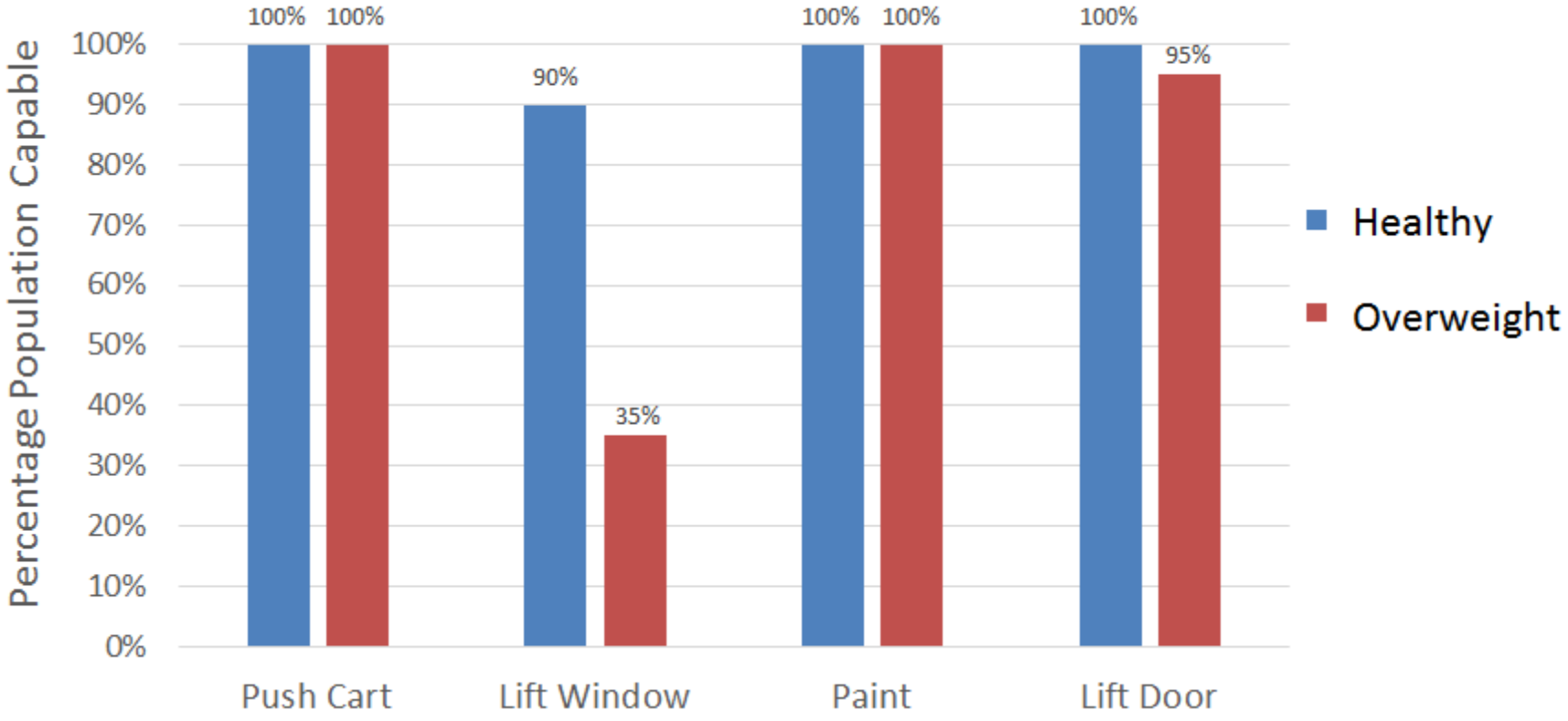
www.hwce.org

Compare Model Capabilities While Completing Common Work Tasks

HEALTHIER WORKFORCE CENTER FOR EXCELLENCE

www.hwce.org

Results: Maximum Right Shoulder Torque



- Current work task design demands exceed right shoulder torque capability of 65% of overweight BMI population and 10% of healthy BMI population

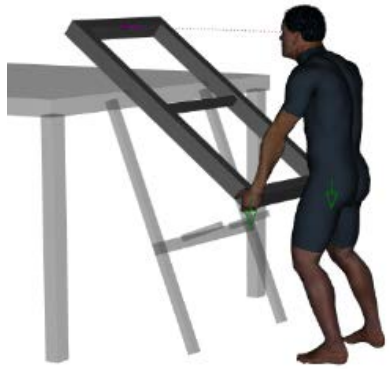
HEALTHIER WORKFORCE CENTER FOR EXCELLENCE

www.hwce.org

Moving Window From Pallet to Conveyor

Walking with window

Lift and place (36 in)

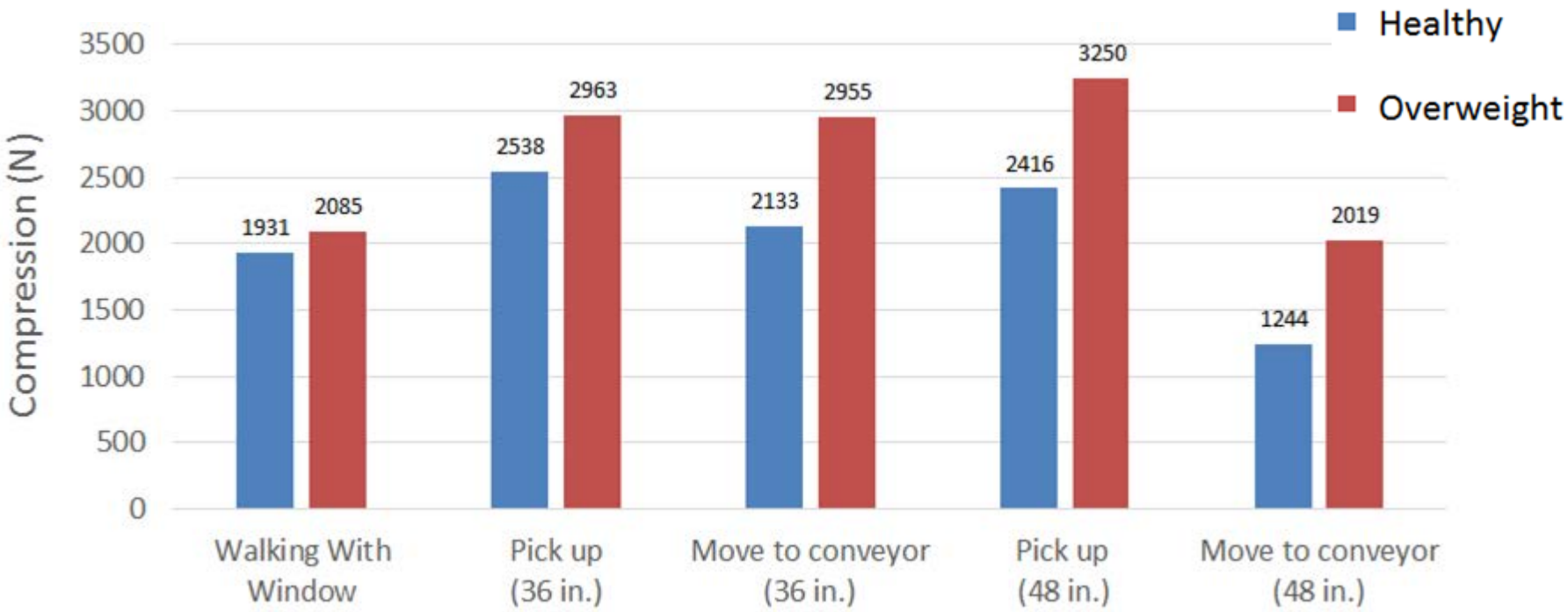


Lift and place (48 in)

HEALTHIER WORKFORCE CENTER FOR EXCELLENCE

www.hwce.org

Results: Spine Compression



- NIOSH recommended action limit for spinal compression is 3400 N (Waters, 1993)
- Work task requiring placing window on 48 in. conveyor is very close to action limit

HEALTHIER WORKFORCE CENTER FOR EXCELLENCE

www.hwce.org

Summary

Digital human modeling software is becoming more sophisticated

Non-occupational risk factors may be modeled

- Age
- Gender
- Joint range of motion limitations

Adds value in context of TOTAL WORKER HEALTH

Questions

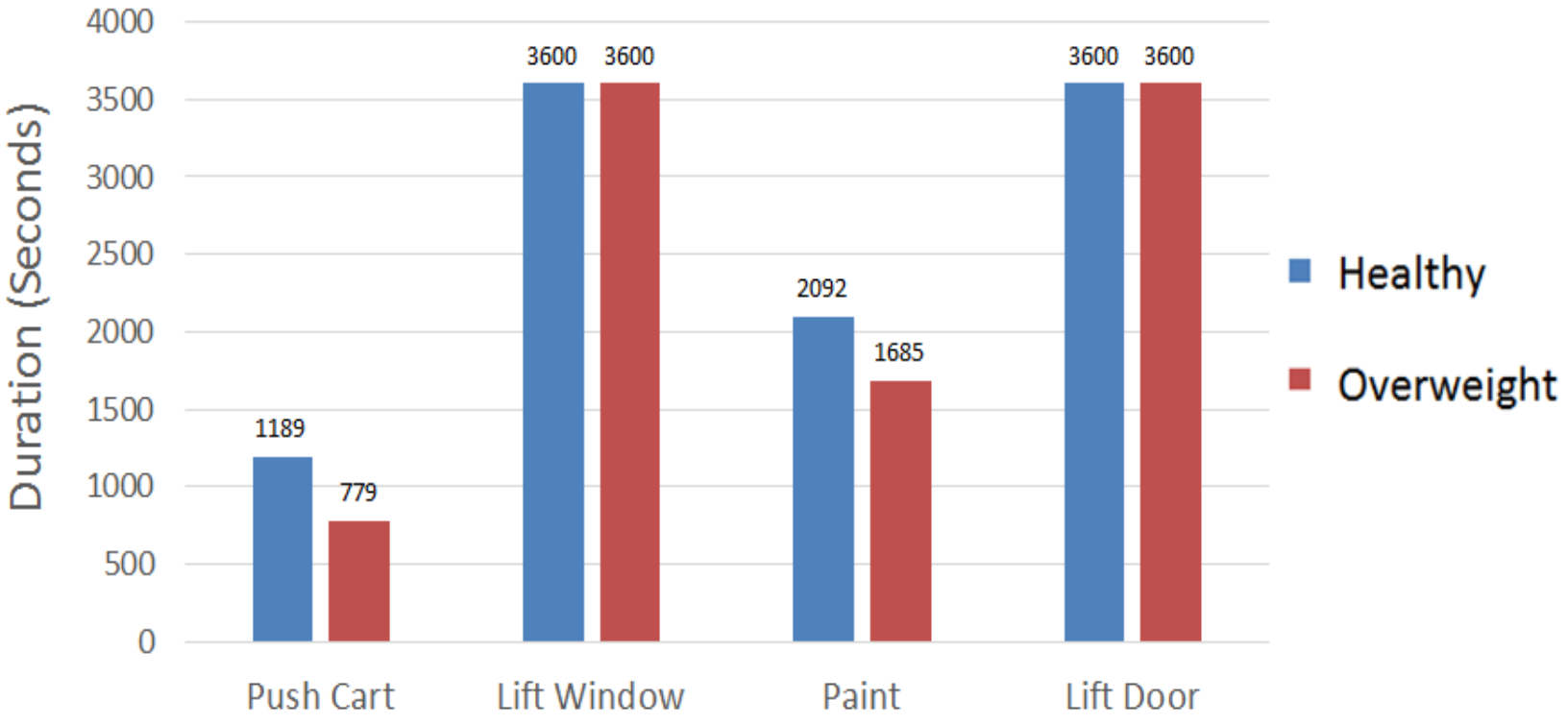
HEALTHIER WORKFORCE CENTER FOR EXCELLENCE

www.hwce.org

References

- Abdel-Malek, K., Yang, J., Kim, J. H., Marler, T., Beck, S., Swan, C., ... & Arora, J. (2007). Development of the virtual-human SantosTM. In *Digital Human Modeling* (pp. 490-499). Springer Berlin Heidelberg.
- Frey Law, L. A., Lee, J. E., McMullen, T. R., & Xia, T. (2010). Relationships between maximum holding time and ratings of pain and exertion differ for static and dynamic tasks. *Applied ergonomics*, *42*(1), 9-15.
- Frey-Law, L. A., Laake, A., Avin, K. G., Heitsman, J., Marler, T., & Abdel-Malek, K. (2012). Knee and elbow 3D strength surfaces: peak torque-angle-velocity relationships. *Journal of applied biomechanics*, *28*(6), 726-737.
- Gerr, F., Fethke, N., Anton, D., Merlino, L., Rosecrance, J., Marcus, M., and Jones, M. P. (2014). A Prospective Study of Musculoskeletal Outcomes Among Manufacturing Workers II. Effects of Psychosocial Stress and Work Organization Factors. Human Factors: The Journal of the Human Factors and Ergonomics Society.
- McGill, S. (2007). *Low back disorders: evidence-based prevention and rehabilitation*. Human Kinetics.
- Potvin, J. R., McGill, S. M., & Norman, R. W. (1991). Trunk muscle and lumbar ligament contributions to dynamic lifts with varying degrees of trunk flexion. *Spine*, *16*(9), 1099-1107.
- Potvin, J. R., Norman, R. W., & McGill, S. M. (1996). Mechanically corrected EMG for the continuous estimation of erector spinae muscle loading during repetitive lifting. *European journal of applied physiology and occupational physiology*, *74*(1-2), 119-132.
- Potvin, J. R., Norman, R. W., & McGill, S. M. (1991). Reduction in anterior shear forces on the L4L5 disc by the lumbar musculature. *Clinical Biomechanics*, *6*(2), 88-96.
- Waters, T. R., Putz-Anderson, V., Garg, A., & Fine, L. J. (1993). Revised NIOSH equation for the design and evaluation of manual lifting tasks. Ergonomics, 36(7), 749-776.
- Xiang, Y., Arora, J. S., & Abdel-Malek, K. (2012). Hybrid predictive dynamics: a new approach to simulate human motion. *Multibody System Dynamics*, *28*(3), 199-224.
- Yang, J., Marler, R. T., Beck, S., Abdel-Malek, K., & Kim, J. (2006). Real-time optimal reach-posture prediction in a new interactive virtual environment. *Journal of Computer Science and Technology*, *21*(2), 189-198.

Results: Left Shoulder Fatigue



- No worker should push cart for more than ≈ 13 minutes (779 sec)
- No worker should paint continuously for more than ≈ 28 minutes (1685 sec)

HEALTHIER WORKFORCE CENTER FOR EXCELLENCE

www.hwce.org