The Dawn of Wearable Ergonomics – Evaluating Exoskeletons in the Field
Briotix Mission, Vision, Values

Transforming Organizations by *Unlocking Human Potential*.

Delivering a competitive advantage through the *application of science* in the physical, cognitive and organizational disciplines.

- Apply our *passion and innovative spirit* to what we do
- Deliver *meaningful results* to every client
- Work in a way that makes our mothers proud
- Care about people
Agenda

• Exoskeleton Introduction
• Ergonomic Problems
  • Injuries
  • Waste
• 2016 Exoskeleton Trials
• Exoskeleton & Wearable Sensor Considerations
Exoskeleton Introduction
If this 1 year old can squat like this, why can’t I?
Interdependent Systems

Neuromuscular Function

Mechanical Capacity

Motor Control
Injury Risk Factors

Research Summary:

- Previous Injury (24)
- Asymmetries (8)
- Motor Control (7)
- BMI (5)

(# prospective studies)
Disparities In Movement Quality And Capacity

Functional Movement Screen (FMS) Results:
This employee failed 5 out of 7 movement tests
He has **prior injuries**
He has **poor motor control**
He has **asymmetrical movement patterns**

Functional Movement Screen (FMS) Results:
This employee failed 1 out of 7 movement tests
He has **no prior injuries**
He has **good motor control**
He has **symmetrical movement patterns**
Posture Matters

**Research Summary:**

- Researchers are attempting to identify the “best” standing or sitting posture (Dolphens, O’Sullivan, Claus, Collins)

- Correlation between various postures and neuromuscular function (Park, Sapsford, Jull, Chan, Tsao; Hodges; Claus, Ainscought Potts, Capson, Collins)

- Correlation between various postures and pain (Dolphens, Straker, Edmondston)
Posture Matters

The Reliability and Validity of the Saliba Postural Classification System
Collins, Johnson, Godwin, and Pappas
JMMT, July 2016

Vertical Compression Test (VCT): Shoulder Mean Vertical Force

Mean increase in force with correct posture 20 lbs

Elbow Flexion Test (EFT): Forearm Mean Vertical Force

Mean increase in force with correct posture 22 lbs
Work Related Injuries Are A Problem

80% of people will have back pain in their lifetime

$50 billion/year spent in USA on low back injuries

Back pain is the leading cause of disability worldwide, causing more lost workdays than everything except the common cold
Nature Of Injuries Requiring Days Away From Work

% distribution for occupational injuries and illnesses with days away from work by selected nature of injury or illness, all ownerships, 2015

- 37% Sprains, strains, tears
- 21% Soreness, pain
- 16% Cuts, lacerations, punctures
- 9% Buise, contusions
- 9% Fractures
- 9% All other nature of injury or illness

Total cases: 1,153,490

Causes Of Injuries Requiring Days Away From Work

Chart C. Incidence rates for occupational injuries and illnesses with days away from work by selected detailed events or exposures, all ownerships, 2011-15

- Falls on the same level
- Struck by object or equipment
- Overexertion in lifting, lowering

Source: U.S. Bureau of Labor Statistics
Chart A. Incidence rates for occupational injuries and illnesses with days away from work by selected occupations, 2011-15

Note: These occupations had at least 0.1 percent of employment and among the highest case counts in their respective ownership classes.
Source: U.S. Bureau of Labor Statistics
Work System Waste

Skills

Defects

Over-Processing

Transport

Inventory

Motion

Waiting

Over-Production

Waste

Work System Waste

Skills

Defects

Over-Processing

Transport

Inventory

Motion

Waiting

Over-Production

Waste
Exoskeleton Applications

- Industry
- Defense/Military
- Rehabilitation
- Mobility
- Recreation/Sports
- Prosthetics & Orthotics

Exoskeleton Categories

- Power Suits
- Power Armor
- Powered Exoskeletons
- Powered Orthotics
- Ergosuits
- Exosuits
- Powered Assist Devices
- Passive Exoskeletons

Source: Exoskeleton Report 2016
Industrial Exoskeleton Types

- Full Body Power Suits
- Supernumerary Robot Arms
- Tool Holding
- Back, Shoulder & Leg Support
- Chair-less Chairs
- Power Gloves

Source: Exoskeleton Report 2016
Exoskeletons for industrial application and their potential effects on physical work load.

Show full citation

Abstract
The aim of this review was to provide an overview of assistive exoskeletons that have specifically been developed for industrial purposes and to assess the potential effect of these exoskeletons on reduction of physical loading on the body. The search resulted in 40 papers describing 26 different industrial exoskeletons, of which 19 were active (actuated) and 7 were passive (non-actuated). For 13 exoskeletons, the effect on physical loading has been evaluated, mainly in terms of muscle activity. All passive exoskeletons retrieved were aimed to support the low back. Ten-forty per cent reductions in back muscle activity during dynamic lifting and static holding have been reported. Both lower body, trunk and upper body regions could benefit from active exoskeletons. Muscle activity reductions up to 80% have been reported as an effect of active exoskeletons. Exoskeletons have the potential to considerably reduce the underlying factors associated with work-related musculoskeletal injury. Practitioner Summary: Worldwide, a significant interest in industrial exoskeletons does exist, but a lack of specific safety standards and several technical issues hinder mainstream practical use of exoskeletons in industry. Specific issues include discomfort (for passive and active exoskeletons), weight of device, alignment with human anatomy and kinematics, and detection of human intention to enable smooth movement (for active exoskeletons).
Field Trial #1: SuitX Modular Agile Exoskeleton (MAX)

MAX components: BackX, LegX, ShoulderX, Balancing Tool Holder
SuitX MAX Trial – BackX In Meat Dept
SuitX MAX Trial – BackX In Tire Dept
SuitX MAX Trial – BackX In Produce Dept
BackX EMG Data

Electromyography (EMG) Test Result

- Without TSE
- With TSE

EMG (µV)

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Without TSE (µV)</th>
<th>With TSE (µV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>4</td>
</tr>
</tbody>
</table>

Reduction:
- 1: 51% Reduction
- 2: 62% Reduction
- 3: 75% Reduction
- 4: 76% Reduction

1. Left Lumbar Erector Spinae
2. Right Lumbar Erector Spinae
3. Left Thoracic Erector Spinae
4. Right Thoracic Erector Spinae
BackX Survey Data (n=5)

- 3/5 felt the exo would reduce work related fatigue
- 3/5 felt the exo would improve work performance
- 4/5 felt the exo would help them manage musculoskeletal health
- 4/5 would use the exo for at least part of their work day
- The exo can be worn over work clothing and under a jacket
- The fit of the exo is very important for comfort and successful outcomes
Field Trial #2: StrongArm Technologies FLx Ergoskeleton

V22 Ergoskeleton

FLx Ergoskeleton
V22 & FLx Ergoskeleton Details

V22 Ergoskeleton is considered a Load Re-Distribution Lift Assist Device

FLx Ergoskeleton is considered a Postural Support Device
StrongArm Trial – FLx Ergoskeleton In Meat Dept

Before

After
FLx Ergoskeleton Survey Data (n=3)

• The workers felt the exo provided them with a reminder to avoid bending and twisting via tactile cues from the device – “It talks to me”
• The workers felt the belt provided some low back bracing
• The exo can be worn over work clothing and under a jacket
• The fit of the exo is very important for successful outcomes
What We’ve Learned

• Humans are not created equal, but jobs are designed one way
• Injuries are a huge problem
• Exoskeletons and wearable sensors are here
• Traditional ergonomic assessment methods are not sensitive to exoskeleton benefits
• Wearable sensor technology may be the best way to evaluate exoskeleton technology in the field
• Further research is needed
Considerations for Industrial Exoskeletons

- **Goal**
- **Powered or Passive**
- **Body Part & Joints Involved**
- **Movement Limitation**
- **Fatigue**
- **Balance**
- **Size & Weight**
- **Clothing, PPE, Tool Belts**
- **Adjustability, Comfort & Fit**
- **Don/Doff Time & Complexity**
- **Pitfalls**
Considerations for All Wearable Technology

Wearability
Usability
Customization
Durability
Ergonomics
Overload
Satisfaction
Pitfalls

Proceedings of the Human Factors and Ergonomics Society Annual Meeting
Technology Can Improve Quality Of Life
Let’s Put Technology to Work for Us
Thank You!

Matthew Marino, PT, MSPT, CPE, CWcHP, CSCS, TSAC-F, CPT, FMS
Lead Ergonomist with Briotix Inc.
matthew.marino@briotix.com
503-863-6062