Spine Research:
Current and Future

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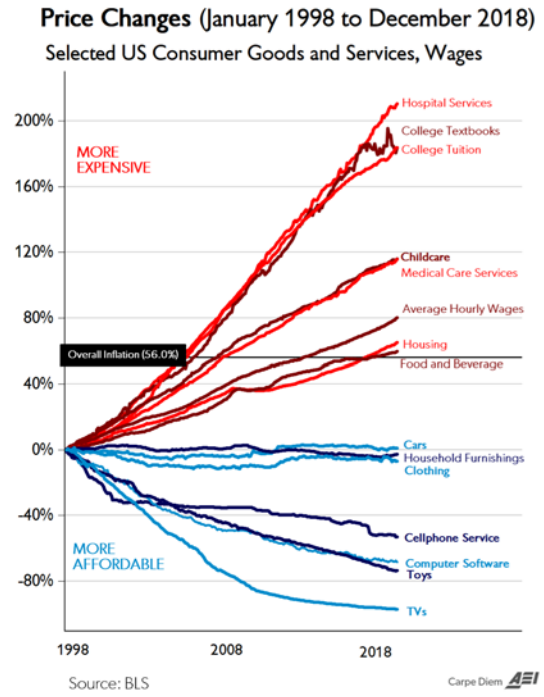

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Low Back Pain (LBP)

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Plenary Address – IEA 2000, San Diago, CA

"The American economy is increasingly post industrial, with less heavy labor, more automation and more robotics, and medicine has consistently improved diagnostic imaging of the spine and developed new forms of surgical and non-surgical therapy. But work disability caused by back pain has steadily risen."

Richard Deyo
Scientific American
August, 1998

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Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015

GBD 2015 Disease and Injury Incidence and Prevalence Collaborators*

Background Non-fatal outcomes of disease and injury increasingly detract from the ability of the world's population to live in full health, a trend largely attributable to an epidemiological transition in many countries from causes affecting children, to non-communicable diseases (NCDs) more common in adults. For the Global Burden of Diseases,

Lancet 2016; 388: 1545-602
This online publication has been corrected. The corrected version

	Prevalence (thousands)		Percentage change (%)
	2005	2015	
Low back pain	460 164 (444 680–477 119)	539 907 (521 449–559 556)	17·3 (16·5 to 18·2)*

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Leading causes 1990	Leading causes 2005	% change number of YLDs 1990–2005	% change all-age YLD rate 1990–2005	% change age-standardised YLD rate 1990–2005	Leading causes 2015	% change number of YLDs 2005–15	% change all-age YLD rate 2005–15	% change age-standardised YLD rate 2005–15
1 Lower back and neck pain	1 Lower back and neck pain	34·5	9·4	−1·8	1 Lower back and neck pain	18·6	4·9	−2·1
2 Iron-deficiency anaemia	2 Sense organ diseases	39·4	13·4	2·1	2 Sense organ diseases	25·2	10·8	0·6
3 Sense organ diseases	3 Iron-deficiency anaemia	14·8	−6·6	−0·6	3 Depressive disorders	18·2	4·5	1·0
4 Depressive disorders	4 Depressive disorders	32·9	8·0	0·6	4 Iron-deficiency anaemia	−3·8	−14·9	−11·6
5 Skin diseases	5 Skin diseases	21·9	−0·8	0·5	5 Skin diseases	11·7	−1·2	0·4
6 Migraine	6 Migraine	29·7	5·5	−0·3	6 Diabetes	32·5	17·2	5·4
7 Other musculoskeletal disorders	7 Other musculoskeletal disorders	51·8	23·4	13·5	7 Migraine	15·3	2·0	0·8
8 Anxiety disorders	8 Diabetes	69·2	37·6	20·7	8 Other musculoskeletal disorders	20·5	6·6	1·3
9 Diabetes	9 Anxiety disorders	26·1	2·6	−1·5	9 Anxiety disorders	14·8	1·5	1·0
10 Asthma	10 Asthma	2·6	−16·5	−15·5	10 Oral disorders	22·4	8·2	−0·2
11 Oral disorders	11 Oral disorders	33·9	8·9	−1·6	11 Asthma	9·4	−3·3	−2·3
12 Falls	12 Schizophrenia	36·1	10·7	0·7	12 Schizophrenia	19·5	5·7	0·3
13 Schizophrenia	13 Falls	13·4	−7·8	−13·9	13 Osteoarthritis	34·8	19·2	3·9
14 COPD	14 COPD	22·2	−0·6	−9·8	14 COPD	16·2	2·8	−5·9
15 Autistic spectrum	15 Osteoarthritis	53·0	24·4	6·3	15 Falls	11·3	−1·5	−8·6
16 Haemoglobinopathies	16 Gynaecological diseases	29·1	5·0	−3·4	16 Autistic spectrum	12·3	−0·7	0·6
17 Gynaecological diseases	17 Autistic spectrum	23·2	0·2	0·5	17 Gynaecological diseases	10·7	−2·1	−3·3
18 Intestinal nematode	18 Other mental and substance	32·5	7·8	0·2	18 Drug use disorders	23·6	9·4	8·2
19 Osteoarthritis	19 Drug use disorders	42·1	15·6	11·6	19 Other mental and substance	18·7	5·0	0·3
20 Other mental and substance	20 Haemoglobinopathies	10·8	−9·9	−5·3	20 Medication overuse headache	18·9	5·2	0·6
21 Bipolar disorder	21 Bipolar disorder	29·4	5·2	0·1	21 Bipolar disorder	14·9	1·6	0·5
22 Epilepsy	22 Medication overuse headache	32·6	7·9	−1·5	22 Congenital anomalies	28·5	13·7	14·7
23 Medication overuse headache	23 Epilepsy	10·9	−9·8	−7·9	23 Haemoglobinopathies	4·3	−7·7	−4·9
24 Other unintentional	24 Congenital anomalies	48·9	21·1	22·4	24 Chronic kidney disease	23·8	9·5	0·1
25 Drug use disorders	25 Chronic kidney disease	35·3	10·1	−2·4	25 Ischaemic heart disease	30·2	15·2	−0·3
26 Diarrhoeal diseases	26 Conduct disorder	15·8	−5·8	0·7	26 Alzheimer's disease	38·8	22·8	1·1
27 Conduct disorder	27 Other unintentional	0·7	−18·1	−23·6	27 Cerebrovascular disease	20·7	6·8	−4·2
28 Chronic kidney disease	28 Alcohol use disorders	28·2	4·2	−2·5	28 Alcohol use disorders	11·1	−1·7	−4·5
29 Congenital anomalies	29 Ischaemic heart disease	40·7	14·4	−2·7	29 Epilepsy	−6·4	−17·2	−16·3
30 Alcohol use disorders	30 Diarrhoeal diseases	−2·2	−20·5	−9·9	30 Other cardiovascular	23·9	9·6	0·5
33 Cerebrovascular disease	31 Cerebrovascular disease				33 Conduct disorder			
34 Ischaemic heart disease	33 Alzheimer's disease				34 Other unintentional			
36 Other cardiovascular	34 Other cardiovascular				35 Diarrhoeal diseases			
40 Alzheimer's disease	39 Intestinal nematode				46 Intestinal nematode			

Communicable, maternal, neonatal, and nutritional
Non-communicable
Injuries

Figure 2: Leading 30 Level 3 causes of global YLDs for both sexes combined, 1990, 2005, and 2015, with percentage change in number of YLDs, and all-age and age-standardised rates
Causes are connected by lines between time periods. For the time period of 1990 to 2005 and for 2005 to 2015, three measures of change are shown: percent change in the number of YLDs, percent change in the all-age YLD rate, and percent change in the age-standardised YLD rate. YLD=years lived with disability. COPD=chronic obstructive pulmonary disease.

Why such a Big Problem?
Inability to Assess

- A precise diagnosis is unknown in 80% to 90% of patients with low back pain
- 10-15% diagnosed through imaging
- Evaluations are highly *subjective* (Oswestry, SF-36)
- With no objective evidence; treatment is "trial and error"
- Less than 50% of surgeries are successful

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Spine Research (Prevention): Current

- Hypothesis driven
- Looking outside the body
- Looking inside the body
- Change the exposure through work design
- Iron Man?

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Traditional view of LBP – Hypothesis Driven

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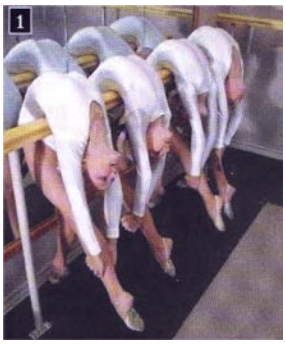
Risk Factor Assessment: How much exposure is too much exposure?

- Can we assess <u>specific</u> spine tissue loads *in-vivo*?



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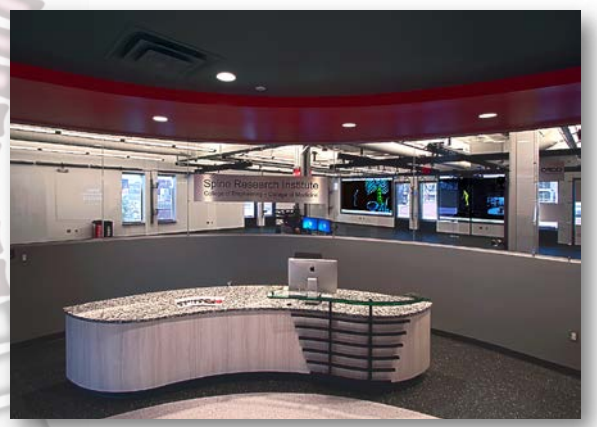
OSU Spine Research Institute



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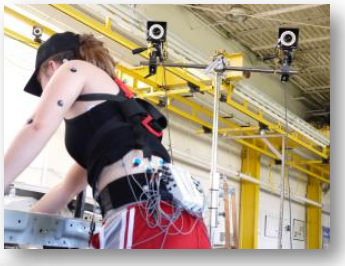
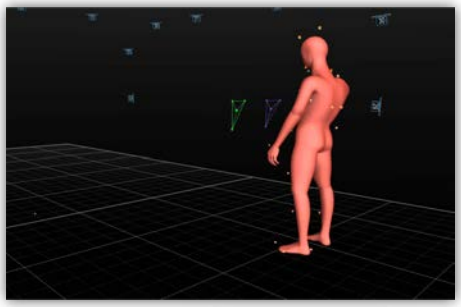
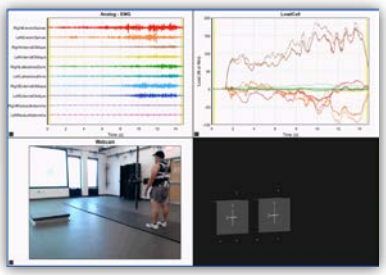
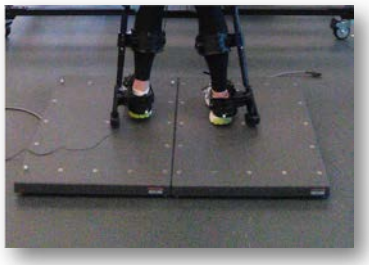
Instrumentation









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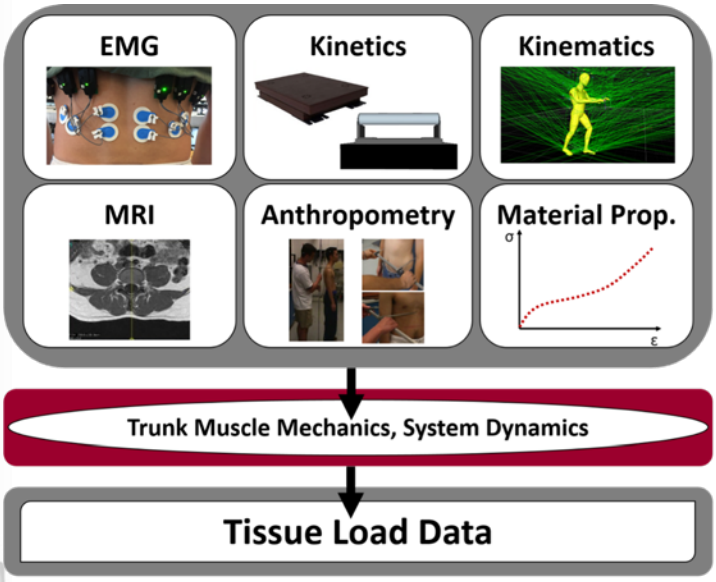
Data-Driven Spine Modeling



Selected References:
Hwang et al. (2016)
Dufour et al. (2013)
Knapik & Marras (2009)
Jorgensen et al. (2001)
Granata & Marras (1995)
Granata & Marras (1993)
Marras & Sommerich (1991)

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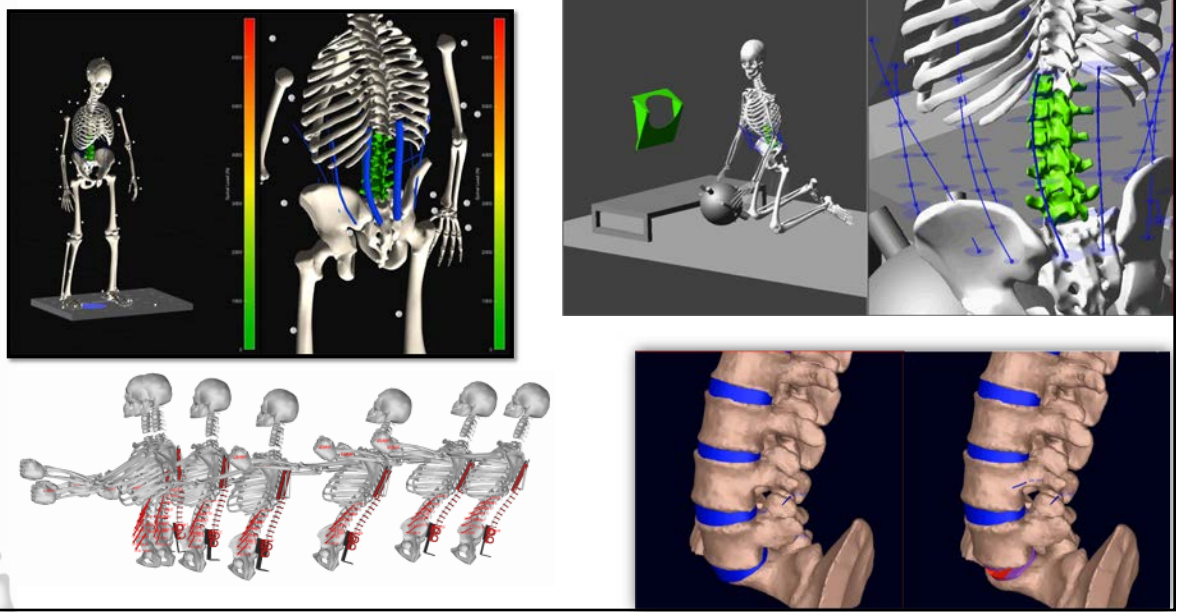
SRI Spine Modeling



Why Dynamics is Important for Risk Quantification

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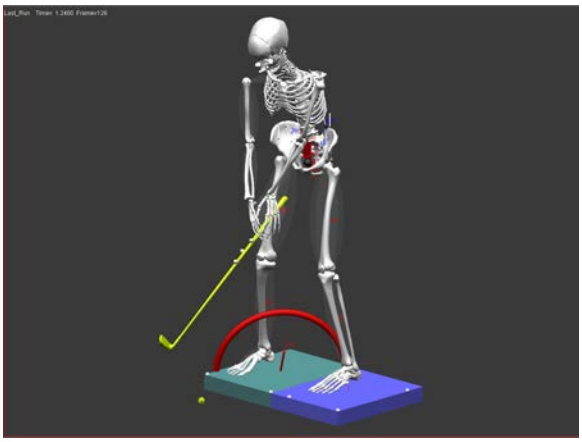
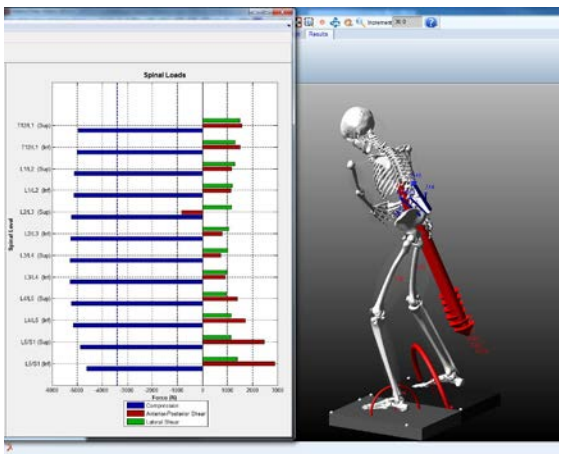
Motion Matters: 6 iron





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SRI Recent Contributions

- Guidelines
  - Two-handed lifting for healthy and LBD workers
  - Biomechanically-determined push/pull guidelines
  - One-handed lifting
- Applied research:
  - Industrial exoskeletons

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Pushing and Pulling Guidelines

Taylor & Francis

Ergonomics

ISSN: 0014-0139 (Print) 1366-5847 (Online) Journal homepage: http://www.tandfonline.com/loi/terg20

Biomechanically determined hand force limits protecting the low back during occupational pushing and pulling tasks

Eric B. Weston, Alexander Aurand, Jonathan S. Dufour, Gregory G. Knapik & William S. Marras

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Motivation

- Manual materials handling burden has shifted to pushing and pulling (de Looze et al. 2000), and up to 20% of LBDs are now attributable to push/pull exposures

- **Prior push/pull guidelines used a psychophysical approach**
  - Lack of association between *subjectively* perceived limits and biomechanical risk (Le et al. 2012)
  - No **biomechanically-determined** guidelines

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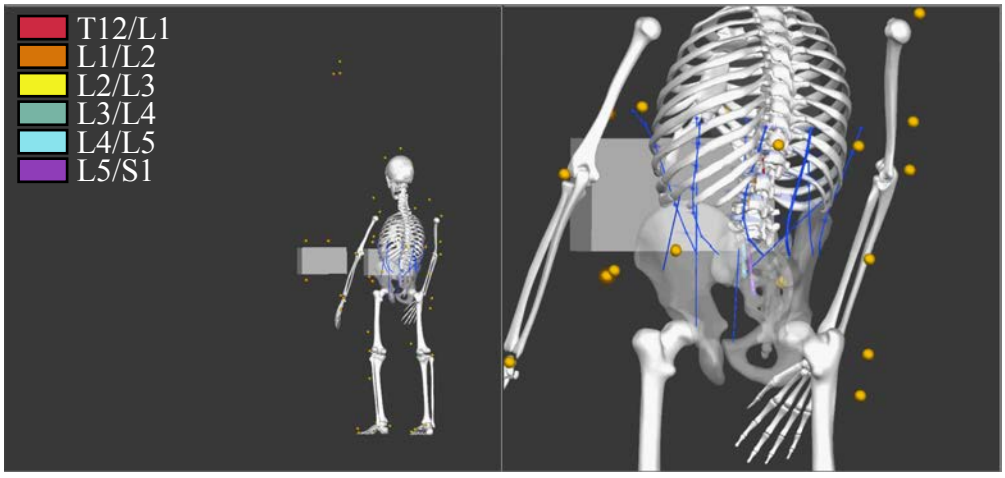
Modeling Spine Forces During Push



3D vectors denote magnitude & direction of spine loads at each lumbar level

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Psychophysical Comparisons

Exertion	Percent Population Protected	Proposed HF Limit (N)	*Snook and Ciriello* Equivalent HF Limit (N)	Percent Change
Straight 2 Hand Push (40 in)	90	213	239	-10.9%
	75	245	300	-18.3%
	50	281	371	-24.3%
	25	316	437	-27.7%
	10	348	503	-30.8%
Straight 2 Hand Pull (40 in)	90	262	240	+9.7%
	75	293	285	+2.8%
	50	327	341	-4.1%
	25	361	391	-7.7%
	10	392	442	-11.3%

Snook and Ciriello (1991) equivalent was initial push or pull at handle height of 37 inches, males and females were averaged

Psychophysically-determined thresholds underestimate biomechanical risk by as much as 30%

Proposed population variance is much smaller than was reported psychophysically

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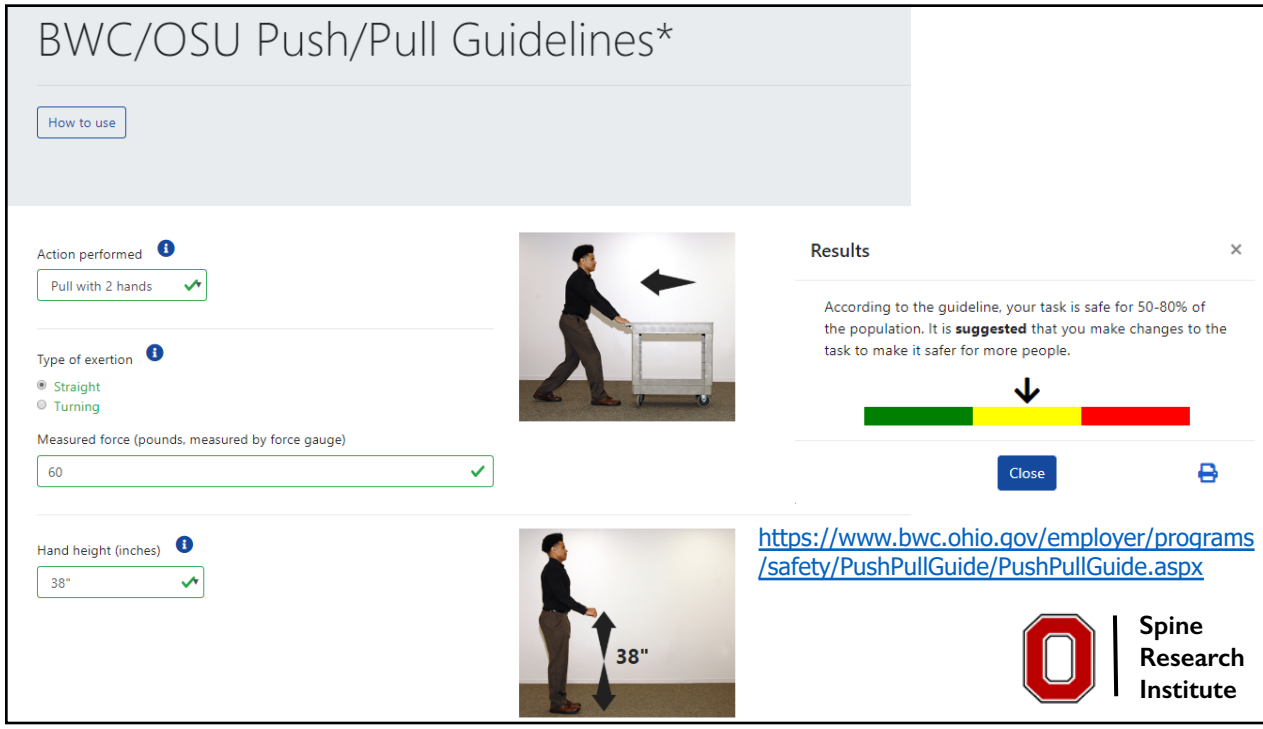
BWC/OSU Push/Pull Guidelines*



https://www.bwc.ohio.gov/employer/programs/safety/PushPullGuide/PushPullGuide.aspx

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One-Handed Lifting Guidelines

Project underway, expected completion in April 2019

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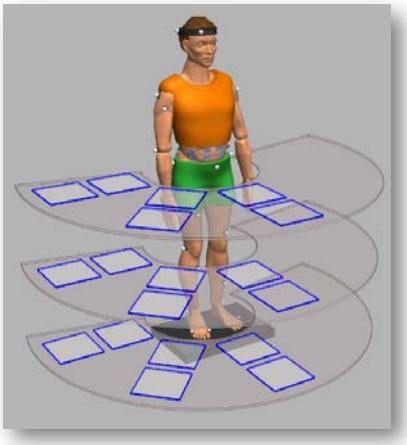
Experimental Design

30 subjects (15 male, 15 female)

Factors Investigated:

- *Hands used to perform lift* (one, two)
- Lift height (ankle, knee, waist)
- Lift asymmetry (0, 45, 90 degrees)
- Load weight (6, 16, 25 pounds)
- Horizontal reach distance (40, 70 cm)

Dependent Measures: peak spinal loads from T12/L1 - L5/S1 in compression & shear



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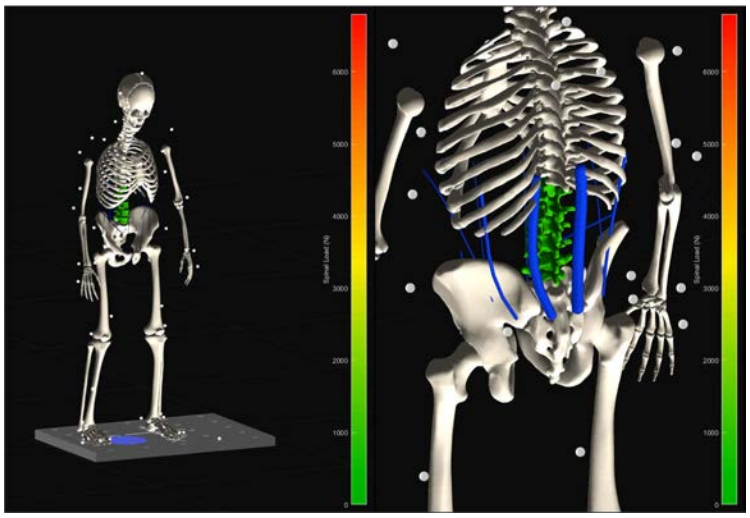
Modeling Tissue Loads on the Spine



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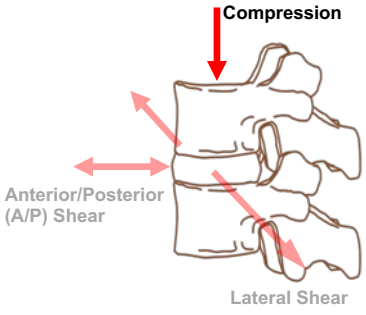
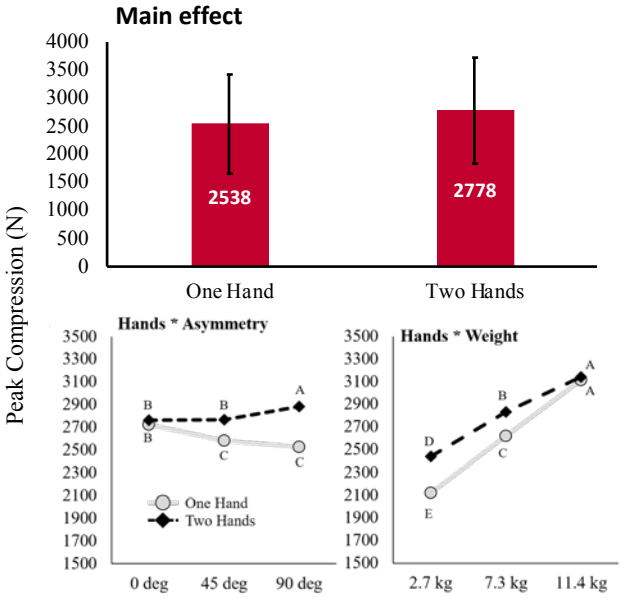
Compression

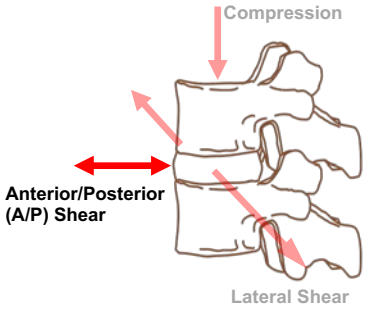
- Peak compression **reduced 8.6% on average** for one-handed lifting compared to two-handed lifting

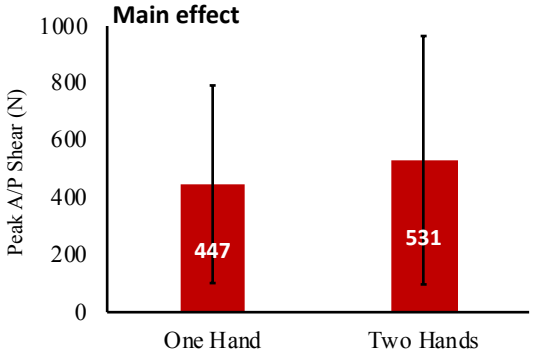




Anterior/Posterior Shear

- Peak A/P shear **reduced 16% on average** for one-handed lifting compared to two-handed lifting





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Implications

- One-handed lifting may be preferred to two-handed lifting if the load to be lifted falls within the strength capability of the worker and can be grasped safely with one hand
- Differences attributable to moment exposure on the lumbar spine due to the weight of the torso
- The impacts of lifting with one vs. two hands are magnified at lower lift origins, further reach distances, lower weights

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Exoskeleton Research

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Biomechanical evaluation of exoskeleton use on loading of the lumbar spine

Eric B. Weston[a,b,*], Mina Alizadeh[a,b], Gregory G. Knapik[a,b], Xueke Wang[b], William S. Marras[a,b]

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Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Impact of two postural assist exoskeletons on biomechanical loading of the lumbar spine

Michael T. Picchiotti[a,b], Eric B. Weston[a,b,*], Gregory G. Knapik[a,b], Jonathan S. Dufour[a,b], William S. Marras[a,b]

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[b] Department of Integrated Systems Engineering, The Ohio State University, Columbus, OH, USA

Project underway

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Motivation

- Their long-term effectiveness is unknown
- Until recently, exoskeletons have yet to be tested with rigorous biomechanical methods
- Previous exoskeleton studies also featured unrealistic test conditions or neglected to investigate potential tradeoffs

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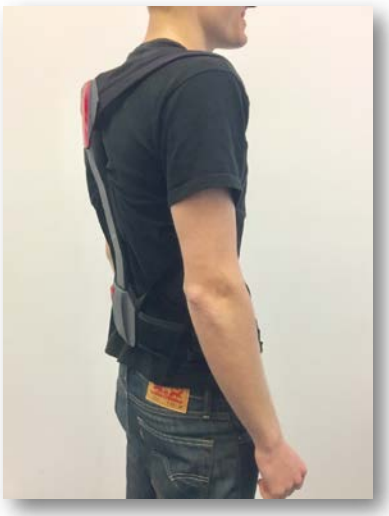
Recent Exoskeleton Research

- **Postural Assist Exoskeleton**
  - Subjects lifted boxes with and without an exoskeleton
  - Exoskeleton led to reduced torso flexion at lower lift origins
  - No Spinal loading changes attributable to the exoskeleton



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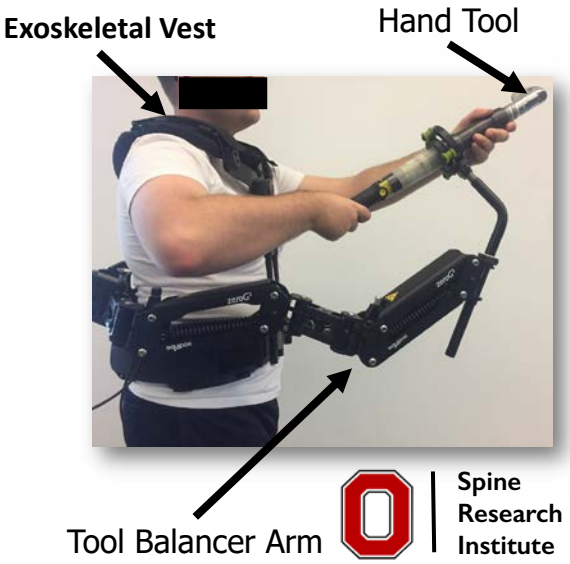
Recent Exoskeleton Research

- **Tool support exoskeleton**
  - Exoskeleton designed to offload the shoulders
  - Significant **increases** in compression (up to 52%) and A/P shear (up to 26%) with exoskeleton use compared to control



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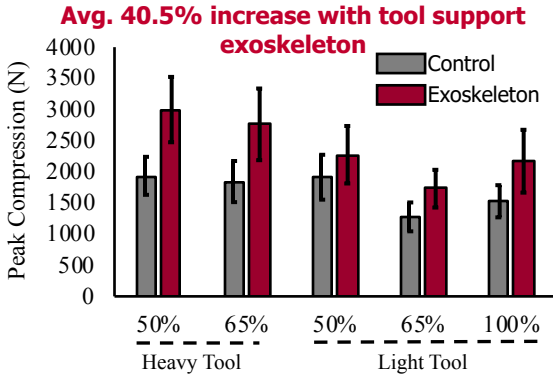
Back Exoskeleton Findings

- Importance of the **human response**
- How **generalizable** are the results?



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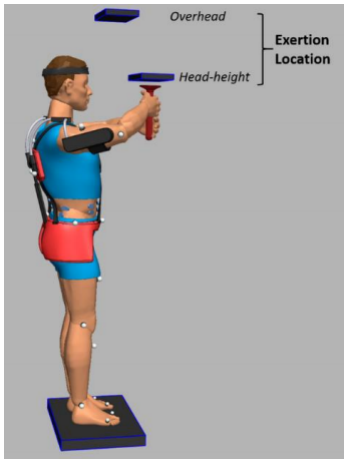
Current Shoulder Exoskeleton Study

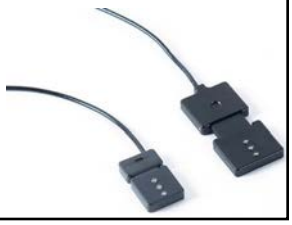
Factors Investigated:

- *Exoskeleton (3 exos + Control)*
- Exertion Location (Head, Overhead)

Dependent Measures:

- **Shoulder fatigue:** oxygenation in R/L anterior deltoid and trapezius
- **Low Back loading:** peak spinal loads

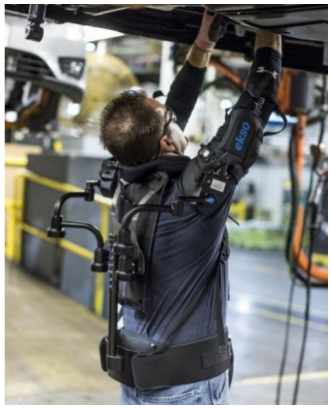




Exoskeletons to be Tested

Levitate Airframe

shoulderX



EksoVest

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Next Spine Frontier

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Spine Research: Future

- Our world has changed
- We don't know what we don't know anymore
- Who needs a hypothesis?
- BACPAC

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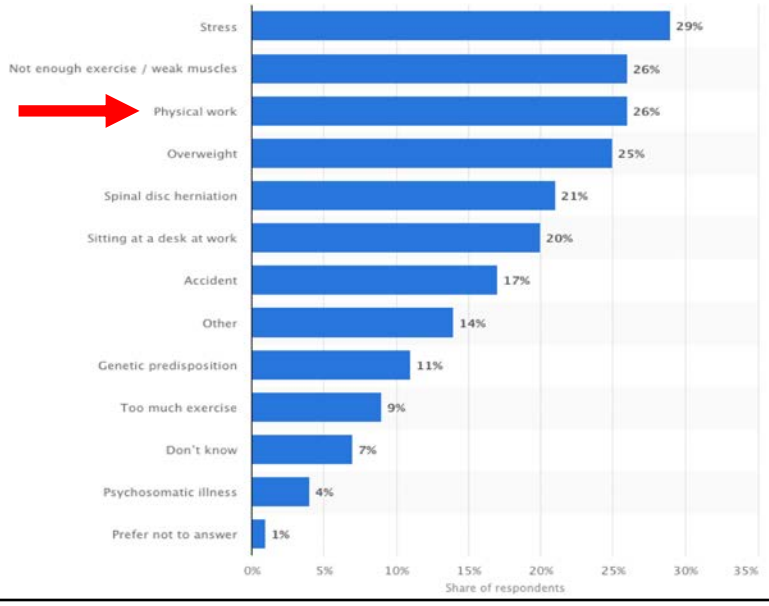
Percentage of Adult in the U.S. who Believe Select Sources were the Cause of their LBP in 2017 (Statistica, 2018)



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Biopsychosocial Care for Chronic Back Pain

BMJ 2015 ; 350 doi: https://doi.org/10.1136/bmj.h538 (Published 18 February 2015)
Cite this as: *BMJ* 2015;350:h538

Richard A. Deyo

Multidisciplinary rehabilitation programs acknowledge that although deranged anatomy or physiology contributes to back pain, psychological factors such as anxiety, depression, and a tendency to catastrophize may amplify or prolong pain.[5] Similarly, social factors such as demands of work, the work environment, or legal action related to back pain affect the nature of pain ...

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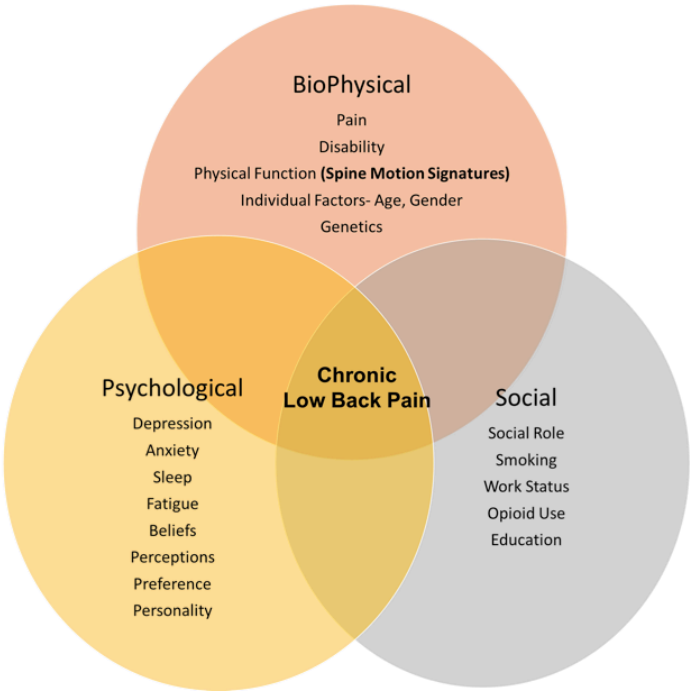

People are Messy

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There is no "Common Back Pain" It's a systems problem and it is Individualized

- Biomechanics
- Personality
- Psychosoical
- Psychological
- Depression
- Individual Factors

NIH BACPAC Effort – Phenotyping Back Pain

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The Mortgage Crisis

Petraeus Under Fire

Presidential Contender

Bonds Breaks a Record — Gets Indicted

2007

The Virginia Tech Tragedy

Goodbye, Harry Potter

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2007

iPhone Mania

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Machine Learning / Artificial Intelligence

Role of Hypothesis in today's world?

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Trump Signs Executive Order Promoting Artificial Intelligence

Robots powered by artificial intelligence at the World Internet Conference, China's big tech event, in Wuzhen last fall. Beijing unveiled a plan in July 2017 to become the world leader in A.I.
Jonathan Browning for The New York Times

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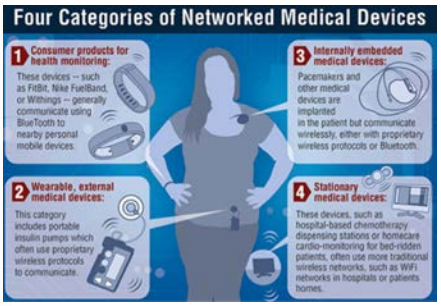

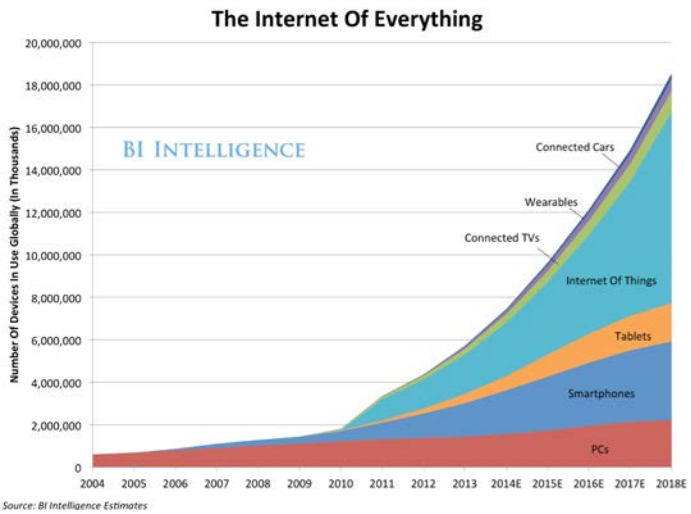

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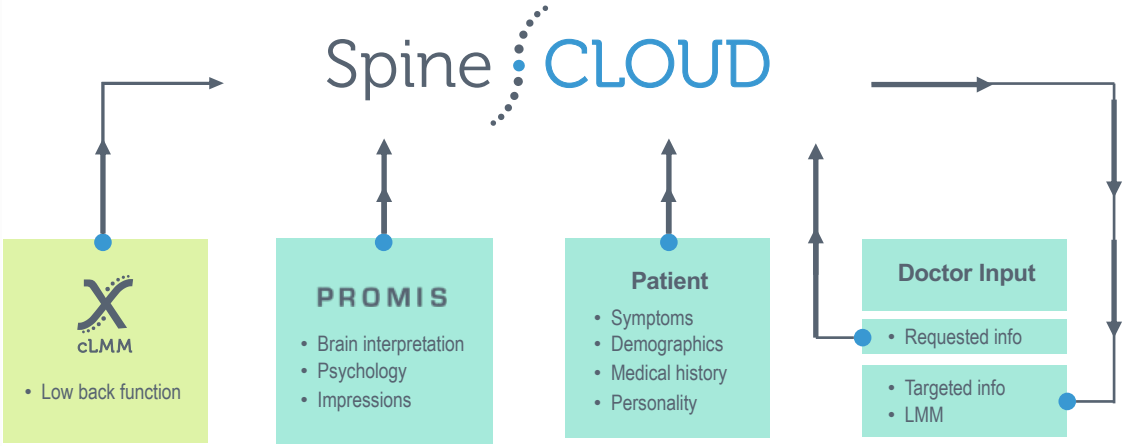
SRI Data Strategy



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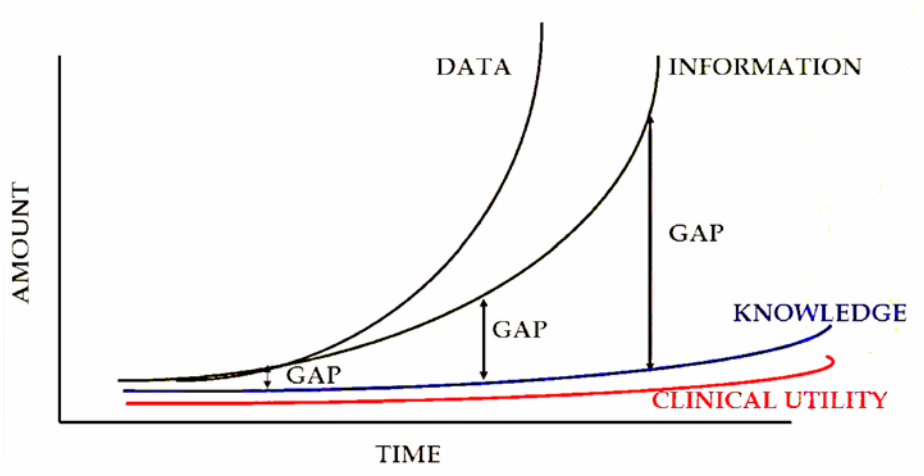
Close the Gap: Data to Knowledge to Utility



Source: Michael N. Liebman, Ph.D.

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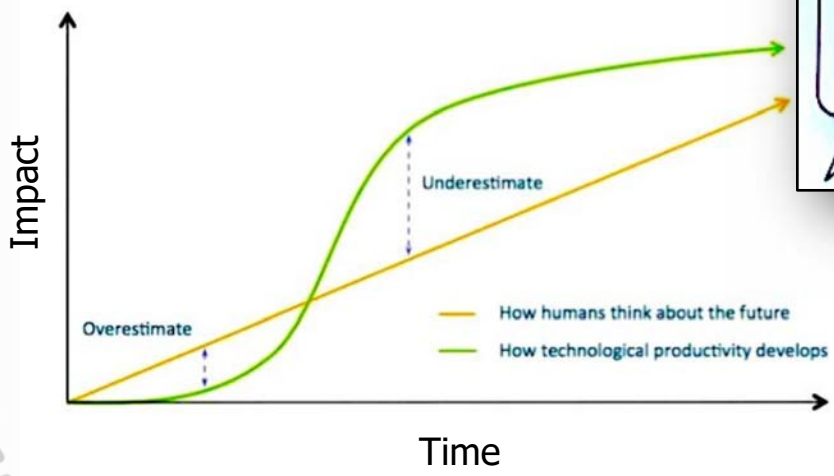
Amara's Law



We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run

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Conclusions:

Understanding Causal Pathways

- Biomechanical causal pathways require system understanding
- Tissue load (ergonomics factors) initiate a cascade of events
- Biomechanical loading is often the *stimulus* for the system
- Low back disorders (and probably pain) are initiated by spine loading due to **A MIX OF**:
  - Physical Exertions
  - Psychosocial and Organizational Influences
  - Individual Factors
- Value of personalized assessments
- Expect that "Big Data" technology will improve our understanding

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Thank You!

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