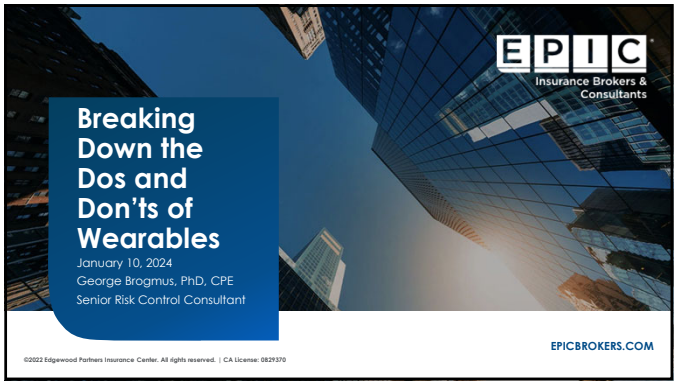
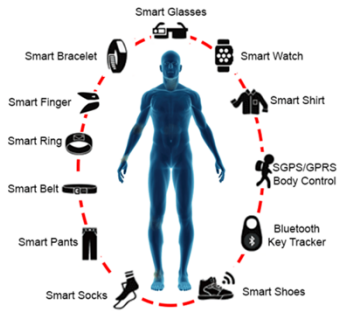


1

Today let's talk about…

- Technology in general
- What are wearables?
- The tech behind wearables
- The keys to successful use of wearables in the workplace
- What to watch out for
- What to watch for
- Exoskeletons
- VR/AR
- A Suggested Approach to New Tech (& Science)



cacm.acm.org – Credit: Heres Arantes Junqueira

2

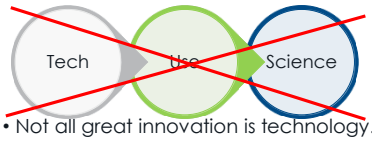
Today Limited to:

Wearables with Occupational Safety Value

3

Generic Comments about Technology

- Nothing is new forever - "New" only lasts a few years
- The pace of tech development is dizzying
- The breadth of tech development is overwhelming
- Delay between science, tech, and application - good or not?



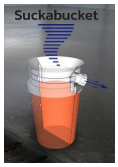
- Not all great innovation is technology…

4

4

The Liberty Mutual Safety Innovation Award in Construction (*New in 2020!*)

- Inaugural 2020 winner: King Kombo by Little Giant Ladders
- Honorable Mention:
  - Suckabucket
  - ITI (Industrial Training International, Inc)



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5

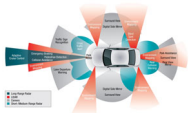
A Footnote…

Three technology categories that aren't really wearables, but have potentially major benefits are:

Vehicle collision avoidance tech (including self-driving and **fatigue identification and mitigation**)

Vision recognition with risk assessment and risk reduction applications (fixed & drone-based camera systems)

Artificial Intelligence

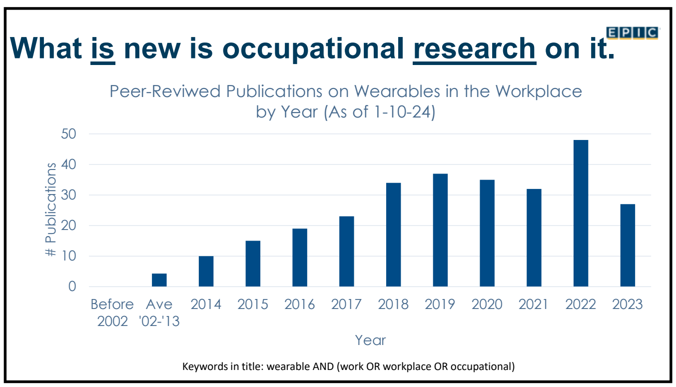


https://commons.wikimedia.org/wiki/File:Figura-.png

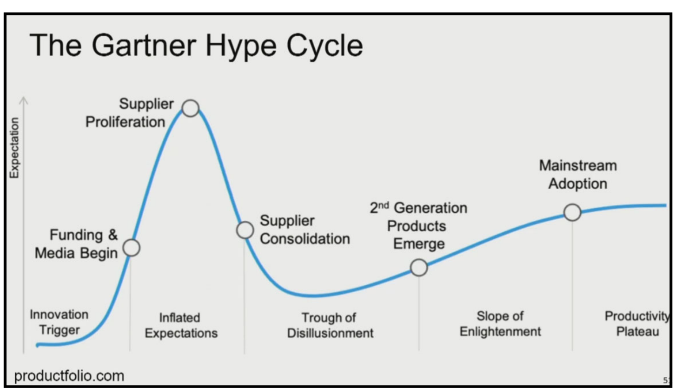
6


Another Footnote…
Wearable technology is NOT new:
• Clothes? – LONG time ago
• Eyeglasses, around 1200 AD (maybe 700 BC!)
• Watches, around 1500 AD
• Abacus ring – around 1600 AD
• Pocket Radio – 1925
• Pacemaker - 1958
See Ometov, A., Shubina, V., Klus, L., Skibińska, J., Saafi, S., Pascacio, P., Flueratoru, L., Gaibor, D.Q., Chukhno, N., Chukhno, O. and Ali, A., 2021. A survey on wearable technology: History, state-of-the-art and current challenges. Computer Networks, 193, p.108074.

7


What is new is occupational research on it.
EPIC
Peer-Reviwed Publications on Wearables in the Workplace by Year (As of 1-10-24)
Publications
50
40
30
20
10
0
Before 2002
Ave '02-'13
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Year
Keywords in title: wearable AND (work OR workplace OR occupational)

8


The Gartner Hype Cycle
Expectation
Supplier Proliferation
Funding & Media Begin
Supplier Consolidation
2nd Generation Products Emerge
Mainstream Adoption
Innovation Trigger
Inflated Expectations
Trough of Disillusionment
Slope of Enlightenment
Productivity Plateau
productfolio.com
5

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What is Wearable Technology?

EPIC

"Wearable technology is any technology that is designed to be used while worn." (Wikipedia)

Movement and posture: Lifting, manual handling	**Physiology:** Vitals, hydration, fatigue, depression
Online instruction & training: AR/VR	**External hazard alerts:** chemical, noise, proximity

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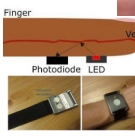
Technology behind Wearables: Sensors

IMU (inertial measurement unit) sensors

- Very accurate
- Machine learning algorithms: steps, gait, energy expenditure, sleep patterns, joint position/movement, falls (elevation/same level), MMH Risk
- Whole Job and Task Assessment

Physiological sensors/biosensors

- Optical or PPG (Photoplethysmography) sensors
  - Infrared light emitting diodes (LEDs), pulse rate sensors
  - Pulse oximeter – illuminates skin, transmits and reflects light to photodiode sensor
  - Reports out heart rate, blood pressure
- ECG – Electrocardiogram (heart signal)
- Bioimpedence sensors
  - Electrodermal (EDA)/ Galvanic skin response (GSR) sensors
    - Hydration, heat stress, lying
- EEG – electroencephalogram (brain waves)
- EMG – electromyography (muscle signal)



Others

- GPS, proximity detection, UV, thermometer, humidity, light, fingerprint, contaminants, etc.

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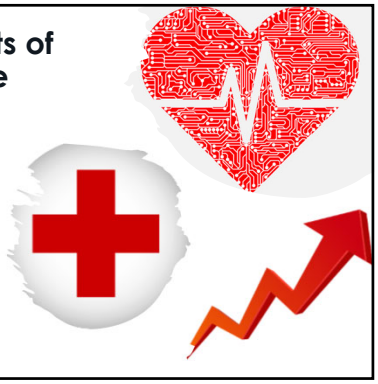
Potential benefits of wearables in the workplace

- Prevent and mitigate injuries
- Decrease extent and duration of disability
- Enhance employee wellness
- Improve costs and productivity



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Applied Ergonomics 78 (2019) 148–156

Employee acceptance of wearable technology in the workplace

Jesse V. Jacobs[a,b,*], Lawrence J. Hettinger[a], Yueng-Hsiang Huang[b,c], Susan Jeffries[a], Mary F. Lesch[a], Lucinda A. Simmons[a], Santosh K. Verma[a], Joanna L. Willetts[a]

EPIC

Recommendations:

- Ensure sufficient evidence to support employees' beliefs that the wearable will meet its objective.
- Focus on improving workplace safety with data recorded only at work.
- Advance a positive safety climate.
- Involve and inform employees in the process of selecting and implementing the wearable technology.

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EPIC

The Bottom-Line Challenge of All Tech

Does it work?

Does it actually reduce risk and reduce injuries/loss?

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EPIC

Red Flags for Questionable Tech

- Based on flawed/faulty assumptions or fallacies
- Focused on a loss area of little impact
- Too new for any validation studies
- Claims of significant risk/injury reduction
- A technology seeking an application

15

What's the right way to lift?

A. Bent knees/straight back (squat)
B. Bend at waist
C. Doesn't matter
D. I don't know

16

Does training to lift correctly reduce back pain?

A. Yes
B. No

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Haptic Wearables

- Premise: Get people to lift correctly.
- Fallacy: The "correct" way to lift.
- Direct value: Zero
- (Possible) Indirect value: identify tasks that require excessive bending

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Fall Detection Wearables

- ✓Home Premise: Alert Caretakers & Emergency Personnel
  - ✓Elderly living alone
- Industrial Premise: Alert Supervision/Emergency Personnel
  - ✓Lone Worker
  - ? Rarely alone
  - ? False positives (and negatives)
- After the fact – too late!
- Predictive fall risk coming (U of Mich)

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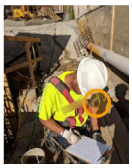
Using an IMU and GPS to zero in on Same-Level Fall Risk

- 16 Construction Workers
- Waist-worn IMU and GPS sensors
- Hard-hat-mounted camera to validate risk
- Previously validated Loss Of Balance (LOB) algorithm on IMU data
- Risk identified where multiple workers had LOB in same area
- 90% of exposures correctly identified
- Mapping allows prioritization of risk reduction
- This tech being commercialized



Each dot is a location where four workers had LOB.

Lee, H., Lee, G., Park, S., Lee, S., Jacobs, J.V. and Ahn, C.R., 2023. Collective Sensing of Workers' Loss of Body Balance for Slip, Trip, and Fall Hazard Identification: Field Validation Study. *Journal of Computing in Civil Engineering*, *37*(1), p.04022052.

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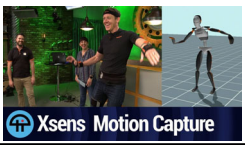
Wearables for Risk Assessment

- Utilize Inertial Measurement Units (IMUs)
- Full 3D Motion Capture (validated accuracy)
- Risk Models can be applied
- Developing Task Identification AI algorithms
- Improving Donning & Offing
- Weight/force estimation coming

SwiftMotion.io – Fuze

University of CA, Berkeley



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Heat Stress – the low hanging fruit of wearables

- Sensor Tech Here Now:
  - Temp
  - Humidity
  - Radiant Heat
  - Exertion Level
  - Activity/Scheduling (work/r
  - Hydration (sweat)
  - Internal Body Temp
  - Heart Rate
- Validated algorithms?
- False Positives – annoying
- False Negatives – potentially deadly
- Superior to a good traditional program?

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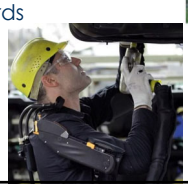
Other Wearables to Watch

- Fatigue-Related Injury
  - Field (U of M)
  - In-vehicle tech (3rd party)
- Chemical/IH Exposure
  - Nano- & Ultrafine-particles
  - NIOSH EVADE (silica)
- Proximity Hazards
  - Vehicle
  - Electrical
  - COVID – 19
- Exoskeletons



Aerosol exposure monitors developed at NIOSH

23

Select the answer that fits your strongest opinion:

A. Exoskeletons have no value for risk reduction
B. Exoskeletons reduce the risk for back pain, but not for shoulder pain
C. Exoskeletons reduce the risk for shoulder pain but not for back pain
D. Exoskeletons reduce the risk for back and shoulder pain
E. Exoskeletons are too expensive
F. Exoskeletons are the latest safety gimmick

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What is an Exoskeleton?

- A wearable external mechanical structure that:
  - Enhances strength
  - Enables mobility
  - Provides protection
- "A user guided robot that is worn by or fits closely to his/her body…" Van der Vorm, et al., 2015
- Draft ASTM F48 Definition: "wearable device that augments, enables, assists, and/or enhances physical activity through mechanical interaction with the body"

Aliens (1986)
20th Century Fox

Elysium (2013)
Tristar Pictures

Avatar (2009)
Lightstorm Entertainment

The Edge of Tomorrow (2014)
Warner Bros Pictures

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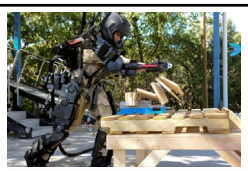
Classifications

- Power
  - Active (actuated: electric, hydraulic, pneumatic)
  - Passive (non actuated: materials, springs, dampers)
- Body part(s) supported
  - Upper extremities, lower limbs
  - Both
  - Single joint (back)
- Application
  - Medical rehab (97% of market)
  - Military
  - Workplace (MMH)



From: Field Assessment of an Arm-Support Exoskeleton: Preliminary Results
Maury Nussbaum, Virginia Tech (Applied Ergonomics Conference, 2019)

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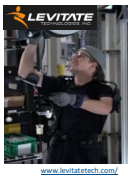
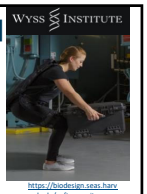
Exoskeletons [http://exoskeletonreport.com/]

- EksoBionics
  - EksoVest
- Equipois
- Sarcos
- Levitate Technologies (Airframe)
- SuitX
- Wyss Institute-Harvard University – Verve Motion
- New ASTM F48 Exoskeletons and Exosuits committee (2017)
  - F48.02 subcommittee-Human Factors and Ergonomics

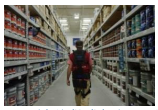


www.levitatetech.com/

http://eksobionics.com/eksoworks/



https://biodesign.seas.harvard.edu/soft-exosuits


https://vtnews.vt.edu/articles/2017/05/eng-lowesexosuit.html


www.sarcos.com


https://vervemotion.com/

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Occupational Exoskeletons: Overview of their Benefits and Limitations in Preventing Work-related Musculoskeletal Disorders

EPIC

Theurel and Desbrosses, 2019

- Reduction of muscular demand "fairly promising"
- "current state of knowledge does not allow for an unreserved endorsement of the use of these technologies for the prevention of MSD."

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Effects of industrial back-support exoskeletons on body loading and user experience: an updated systematic review

EPIC

Kermavnar, et al., 2021

- 33 studies (13 active exos; 20 passive), 2016 to 2019
- Mostly lab studies, mostly healthy young men
- Decreased back-muscle activity, peak L5/S1 moments and spinal compression
- Endurance during lifting and static bending improved
- Performance declined during tasks that required increased agility.
- The overall user satisfaction was moderate.
- Side effects: increased abdominal/lower-limb muscle activity

30

The influence of using exoskeletons during occupational tasks on acute physical stress and strain compared to no exoskeleton – A systematic review and meta-analysis.
Bar, et al., 2021

- 115 Articles Reviewed (63 Qualitative and 52 Quantitative)
- High risk of bias
- Statistically significant effects for BOTH target and non-target body areas
- Reduced energy expenditure
- **"Using an exoskeleton during occupational tasks seems to reduce user's acute physical stress and strain in the exoskeleton's target area. However, impact on workers' health is still unknown, primarily because of missing long-term evaluations under real working conditions. "**

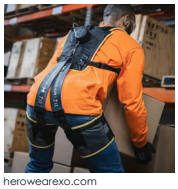
31

Maury Nussbaum, Virginia Tech

Keynote Address, 2022. Exoskeleton Conference. University of Waterloo
Occupational Exoskeletons: Evidence of the Benefits, Potential Limitations, and Future Research Needed
https://www.youtube.com/watch?v=5vXkv7153hc

- Still more questions than answers (is risk reduced, better fit, guidelines developing)
- Manufacturer claims not yet substantiated
- Prediction: "The future is active, smart, and soft"
- Challenge to match worker & task with Exo
- Be aware of adverse effects
- Start small - Pilot
- The good Exo companies are honest
- Benefits still uncertain
- Tech keeps changing/***improving***


vervemotion.com


herowearexo.com

32

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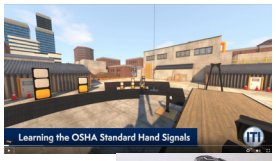
My Exoskeleton Take-Aways

- Very "hot" area of research
- Upper Extremity Exoskeletons
  - Price point ~$5,000 (passive)
  - Positive lab results for:
    - Increased performance
    - Decreased discomfort
    - Reduced energy expenditure
    - Reduced muscle activity
    - Long-term field deployments being evaluated by NIOSH research
- Back (and posture-altering) Exoskeletons
  - Only VERY recently showing any potential benefits (soft)
- Discomfort still an issue
  - (BUT Soft Exosuits - used up to 14 hours continuously)
- Clearance, PPE, fall risk concerns continue
- **Can expect a large percentage of back pain to continue even with perfected technology**
- **Highly recommend:** https://blogs.cdc.gov/niosh-science-blog/2022/05/05/msd-webinars/

33

Virtual Reality

- Mostly used for training
  - Safe environment for errors
  - Consistent Instruction
- VR headsets: Cybersickness, Eye strain, discomfort, dizziness, nausea
- Simulation of work (3-D, w/ Analysis)



Apple Vision Pro

Jack simulation and analysis

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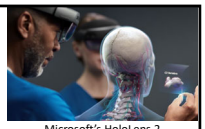
Augmented Reality

- Remote consulting
- Facilitate manufacturing
- Not all systems require a headset:
  - Glasses
  - Tablet
  - Phone



Microsoft's HoloLens 2

Apple Vision Pro

https://www.reliableplant.com/Read/31709/ar-improve-manufacturing

35

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EPIC

Buyer Beware

Shocking News: Vendors want sales.

More Shocking News: Persuasive Marketing ≠ Truth

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A Suggested Approach to New Technology (& Science)

- Skeptical Optimism
- Start with your priorities, not with just the shiny things.
- Evaluate the options/vendors, including non-tech approaches
- Challenge vendors/developers to produce scientific evidence (and have an interpreter)
- Evaluate potential INCREASED risks
- Evaluate "dependencies" (e.g., needs a phone with RFID reader)
- Engage workers at an early stage
- Ensure use is for ***SAFETY*** at ***WORK*** and data are confidential (Jacobs, et al., 2019)
- Always start small-scale - pilot

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