VIRGINIA TECH

# OCCUPATIONAL EXOSKELETONS AND THEIR POTENTIAL APPLICATIONS IN MINING

VIRGINIA TRANSPORTATION AND CONSTRUCTION ALLIANCE
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FREDERICKSBURG, VA AND ROANOKE, VA

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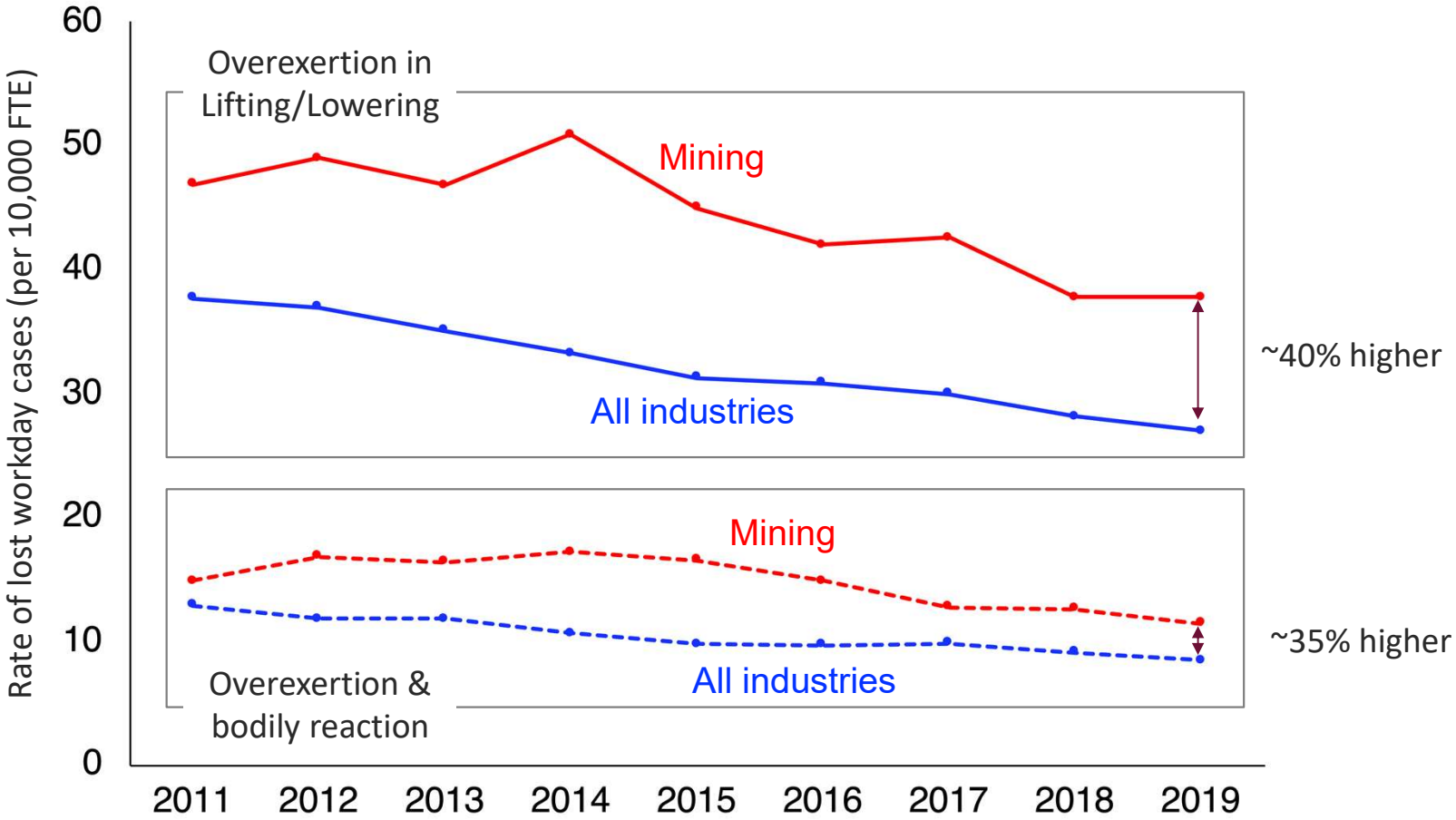
# LOST WORKDAYS

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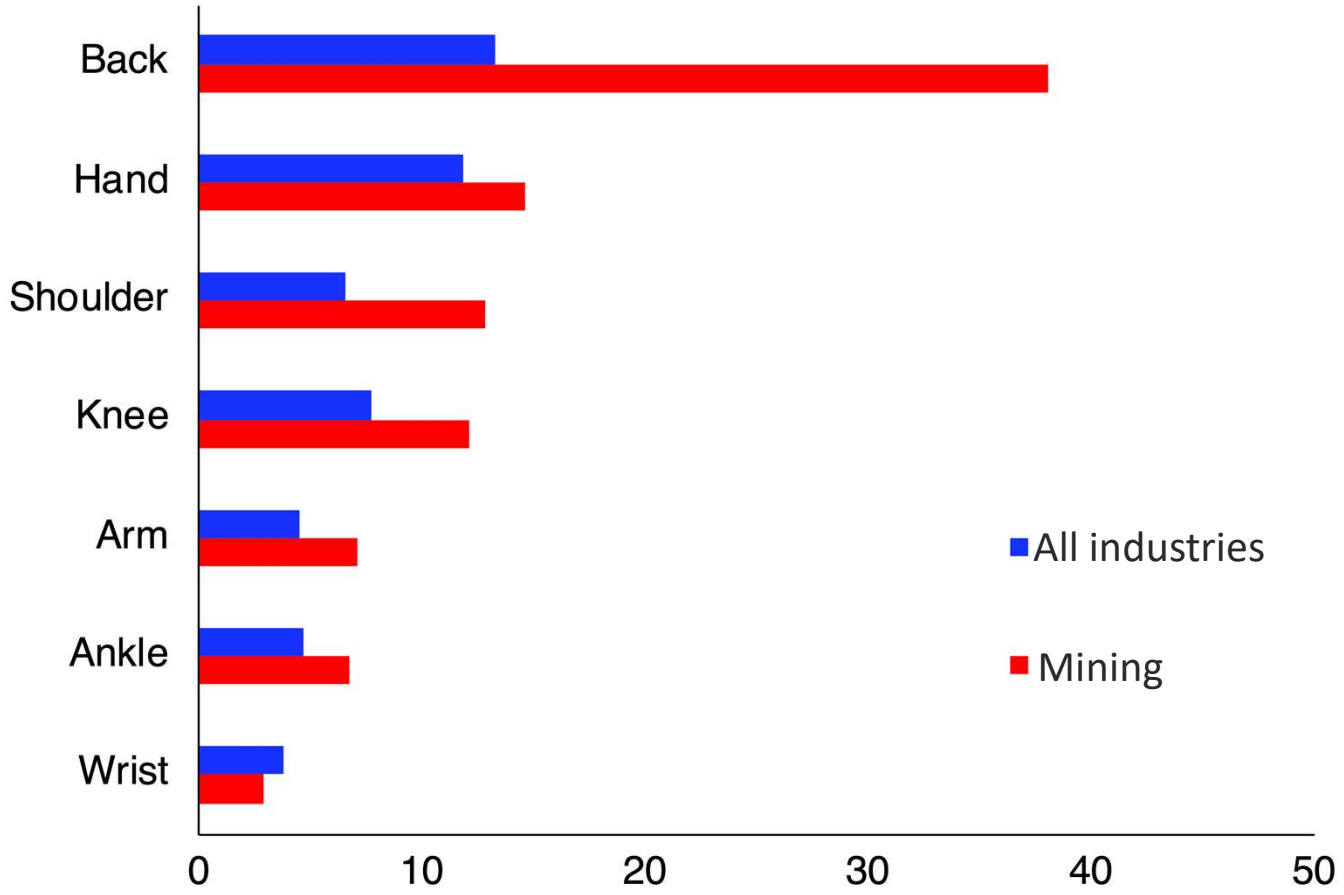
# LOST WORKDAYS BY BODY PART INJURED

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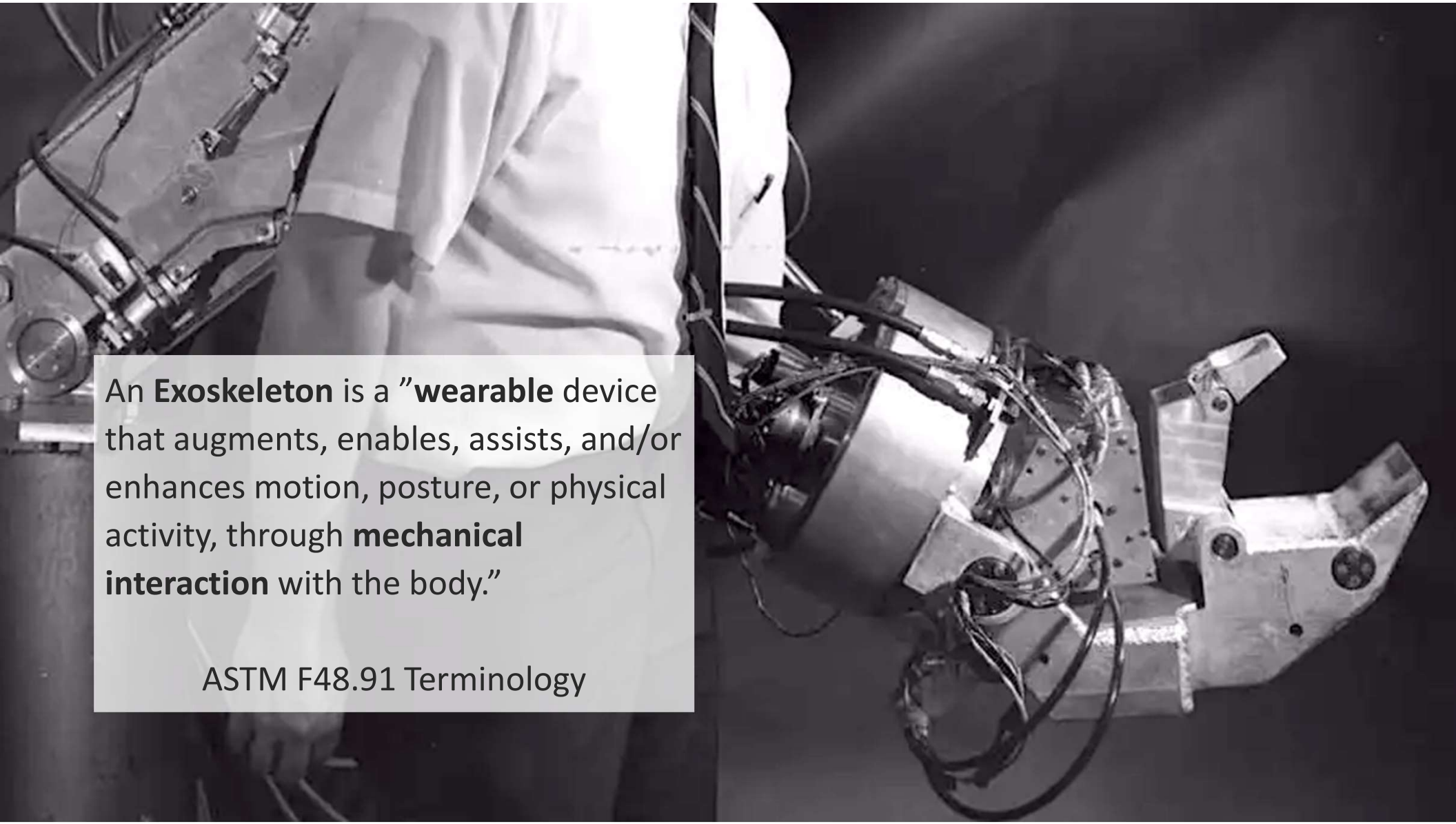
# LOST WORKDAYS BY BODY PART INJURED

*Surface stone mining workers suffer from a high rate of Work Related Musculoskeletal Disorders (WMSDs).* Miners in surface stone operations in the US account for 20.6% of workers in the mining industry (68,514 in 2018), and 23% of all reportable lost time injuries in mining between 2014 and 2018.

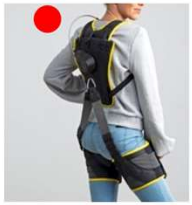
Of the lost time incidents reported to MSHA from 2014 to 2018 in surface stone (including mines and mills), 24.5% were attributed to overexertion, which are the injuries we are targeting with the use of exoskeletons. Over the five-year period analyzed, this incident rate is relatively consistent, indicating that other interventions to improve health and safety outcomes have not been successfully implemented. Thus, there is a critical need for new solutions to control (i.e., reduce and/or prevent) WMSD risks during manual mining tasks.

CDC NIOSH Mining, 2018

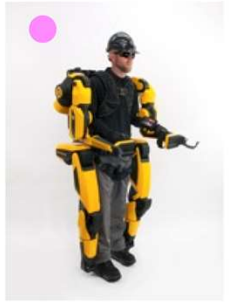
MSHA Accident and Injury, 2018


An **Exoskeleton** is a ”**wearable** device that augments, enables, assists, and/or enhances motion, posture, or physical activity, through **mechanical interaction** with the body.”
ASTM F48.91 Terminology


Cornell
(1961)

2015 2016 2017 2018 2019 2020 2021/2 (expected)



Passive

Active / Powered

● Arm support ● Back support ● Leg support ● Hand support ● Whole-body support

# CURRENT OCCUPATIONAL EXOSKELETONS (EXOS)

Arm Support (16)

Back Support (22)

Leg Support (4)

Power Glove (2)

Tool Holding Exoskeleton (3)

exoskeletonreport.com

Unit mass = 1.54 – 12 kg (3.4 – 26 lb)

Costs = about $3,000 – $8,000

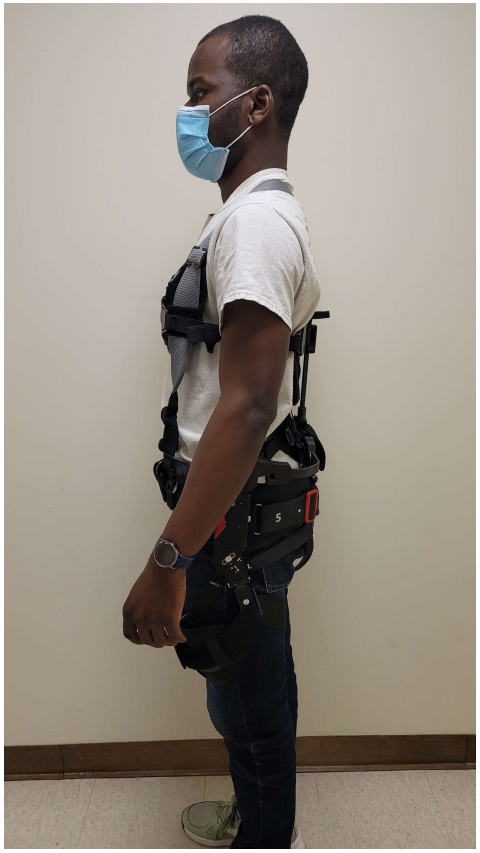
# So, how does an EXO work?


https://www.bigrentz.com/blog/construction-exoskeletons

# PASSIVE ARM SUPPORT


https://www.bigrentz.com/blog/construction-exoskeletons

# PASSIVE BACK SUPPORT

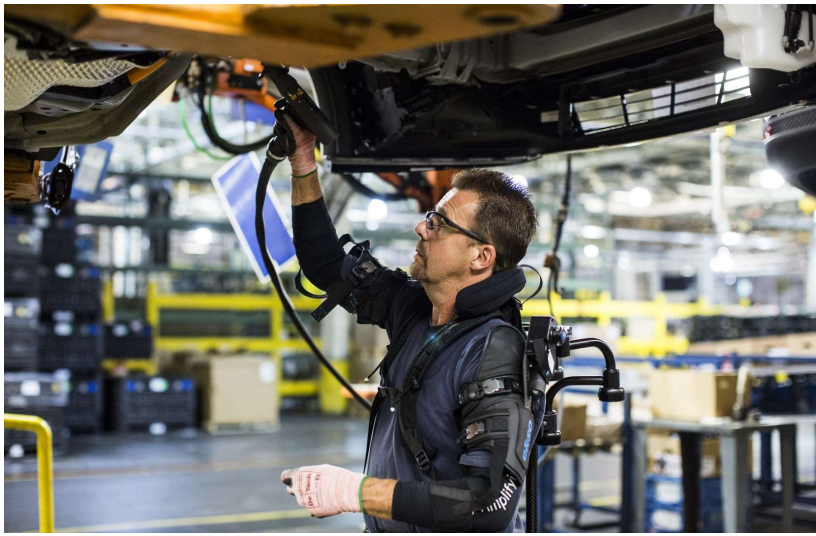



https://www.bigrentz.com/blog/construction-exoskeletons

# FIELD-TESTING EVIDENCE OF ARM-SUPPORT EXOS

- Decrease shoulder muscle activity[1]
- Decrease in shoulder pain[2, 3]
- Decrease in shoulder and neck discomfort[4]
- Decrease heart rate and decrease step rate when walking[5]
- Concerns about thermal discomfort[4]
- Concerns about movement restrictions[5]
- Increase discomfort in pressure points (e.g., chest, back, hips, thighs) [5]
- Suggestive/borderline beneficial effects of ASE use on physical demands [7] (18-month longitudinal study)


[1] Gillette & Stephenson (2019)
[2] Motmans et al. (2019)
[3] Smets (2019)
[4] Amandels et al. (2019)
[5] Marino (2019)
[7] Kim et al. (2021)

# FIELD-TESTING EVIDENCE OF BACK-SUPPORT EXOS

- Decrease back discomfort[1]
- Decrease back muscle activities[2, 3]
- Increase trapezius muscle activity[4]
- Concerns about movement restrictions[4]
- Increase discomfort in pressure points (e.g., chest, back, hips, thighs)[1, 4, 5]
- Increase heart rate and decrease step rate when walking[5]


[1] Hensel & Keil (2019) [2] Motmans et al. (2019)
[3] Omoniyi et al. (2021) [4] Amandels et al. (2019)
[5] Marino (2019)

## SUMMARY OF EXISTING EVIDENCE ON EXO USE

# Benefits and limitations of an EXO depend on EXO design and task demands

**Fitting diverse workers is critical**

- Accounting for anthropometric diversity and gender differences

**Potential for minor-moderate adverse effects**

- Discomfort
- Safety concerns
- Muscle deconditioning
- Long-term evidence
- Etc.

Problem:

There is no mining-specific information

# Project: Exoskeletons as an innovative approach to prevent musculoskeletal disorders in surface stone mining


**PI:** **Maury A. Nussbaum**

**Co-investigators:** **Sunwook Kim, Kray Luxbacher, Divya Srinivasan, & Deborah Dickerson**



**Duration: 9/01/2020 – 8/31/2023**

## SPECIFIC AIMS OF THE PROJECT

**Aim 1: Identify** opportunities in surface stone mining for the application and assessment of EXOs by engaging industry stakeholders

**Aim 2: Quantify** the benefits and risks of EXO use for select manual tasks in surface stone mining

**Aim 3: Refine** initial guidelines for EXO use through the assessment of the perceived safety, effectiveness, and acceptability of EXO use by surface stone mining workers in a realistic context

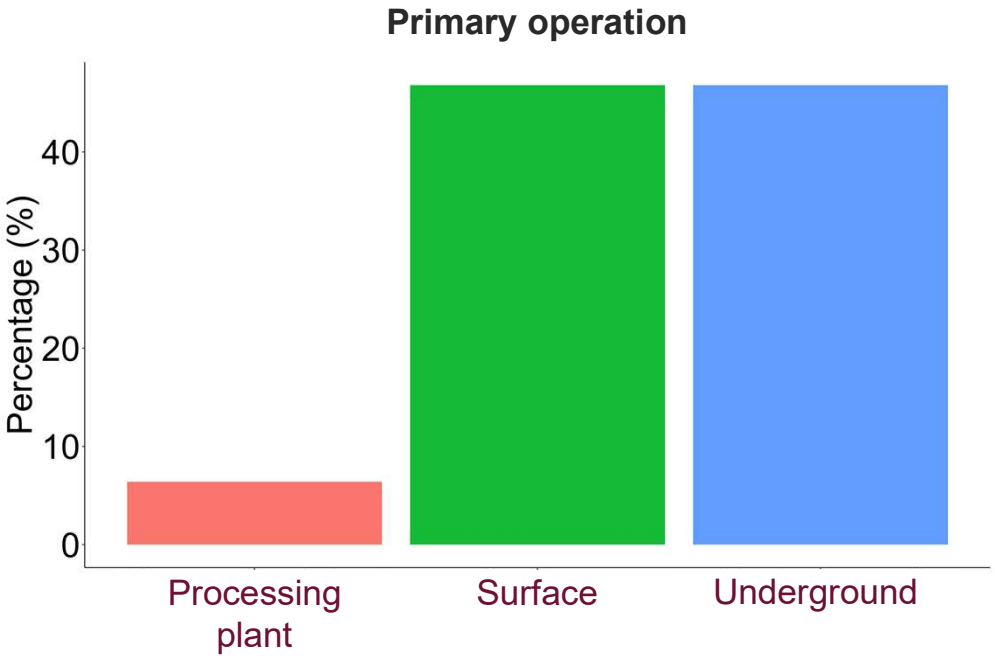
# AIM 1 - APPROACHES

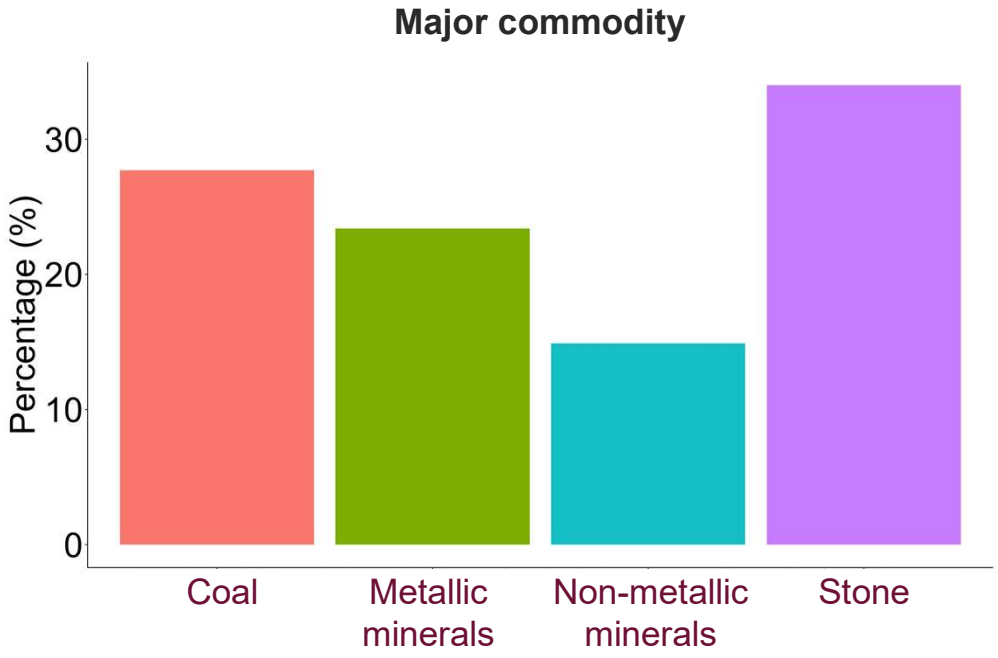
- **Online survey (currently ongoing) focusing on**
  - Work characteristics and risk factors
  - Awareness, concerns, and attitudes regarding EXO
  - Potential tasks that an EXO can be helpful for
- **Semi-structured interview**
  - Obtain more in-depth opinions about EXO use from diverse stakeholders

## PRELIMINARY SURVEY RESULTS (N = 47)

- **Age** = 35 (7.6) years
- **Gender** = 45 males and 2 females
- Years of **industry experience** = 7.4 (5.2) years
- **Current job**
  - Miner (11)
  - Mechanic / Electrician (8)
  - Equipment operator (7)
  - Technician (6)
  - Mining engineer (5)
  - Manager / Coordinator (4)
  - Carpenter (2)

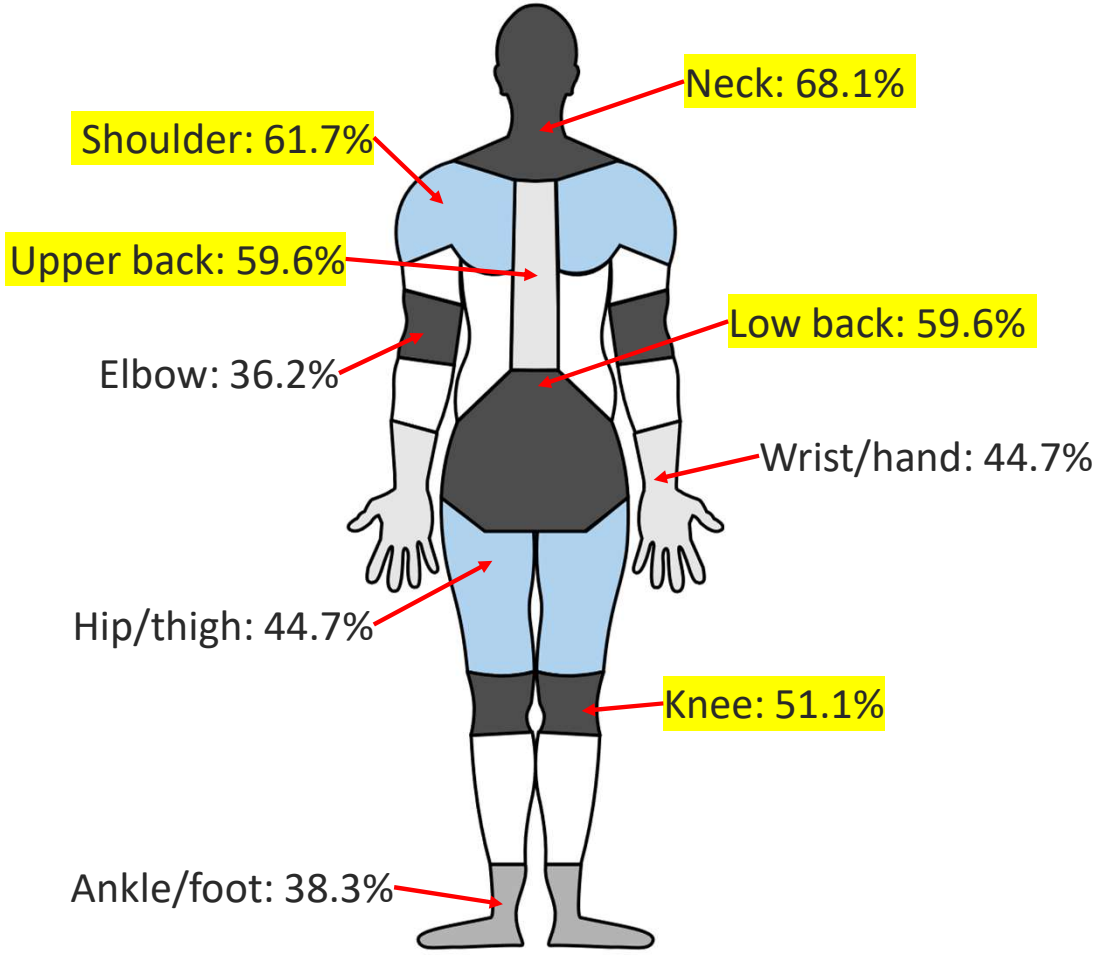
# PRELIMINARY SURVEY RESULTS (N = 47)



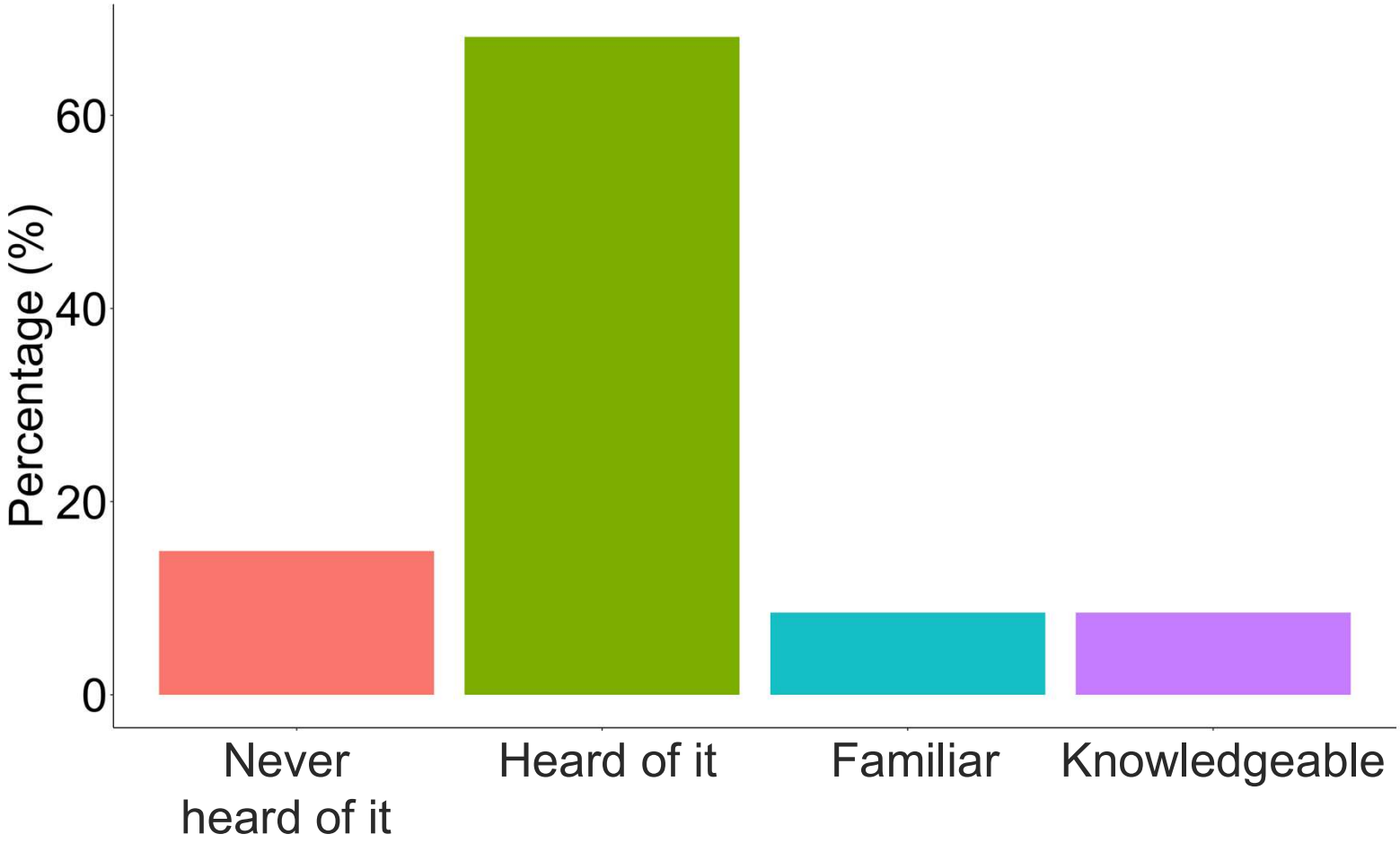



# Musculoskeletal problems

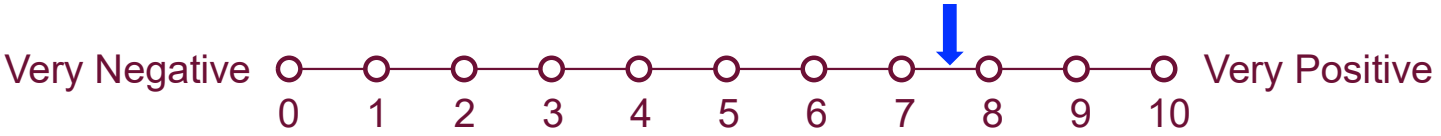
"Have you at any time during the last 12 months had symptoms (such as aches, pain, discomfort, numbness)"



# CURRENT KNOWLEDGE ABOUT EXOS



# FIRST IMPRESSIONS




**Major reasons to accept an EXO**

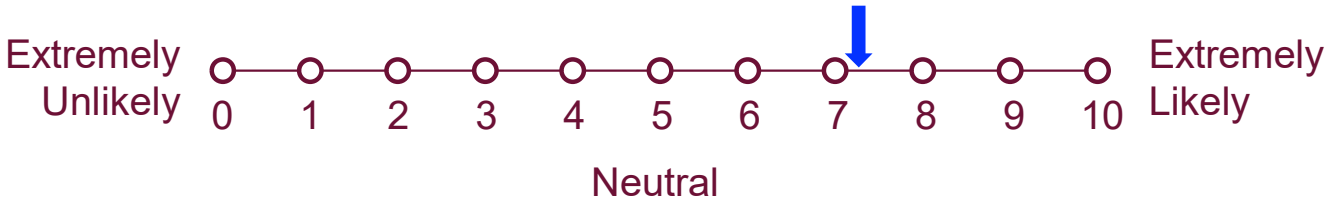
- Help reduce pain, and fatigue
- Prevent injury
- Make job easier
- Can improve job efficiency

**Major concerns**

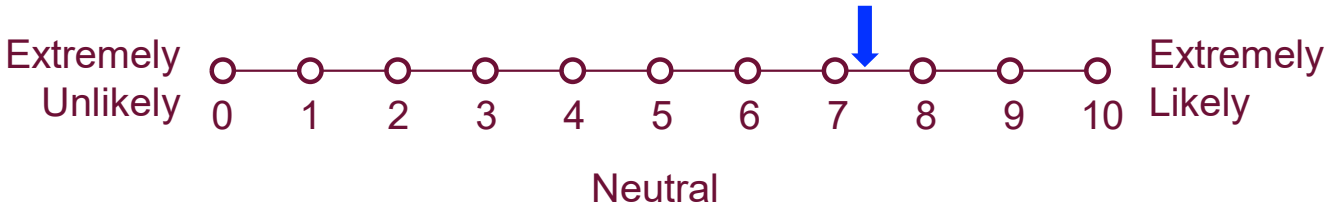
- Movement restriction (especially in confined space)
- Ruggedness
- Comfort
- Costs
- No information of EXO use
- Time to put on

# HOW LIKELY ARE YOU TO USE AN EXO IF AVAILABLE AT WORK?

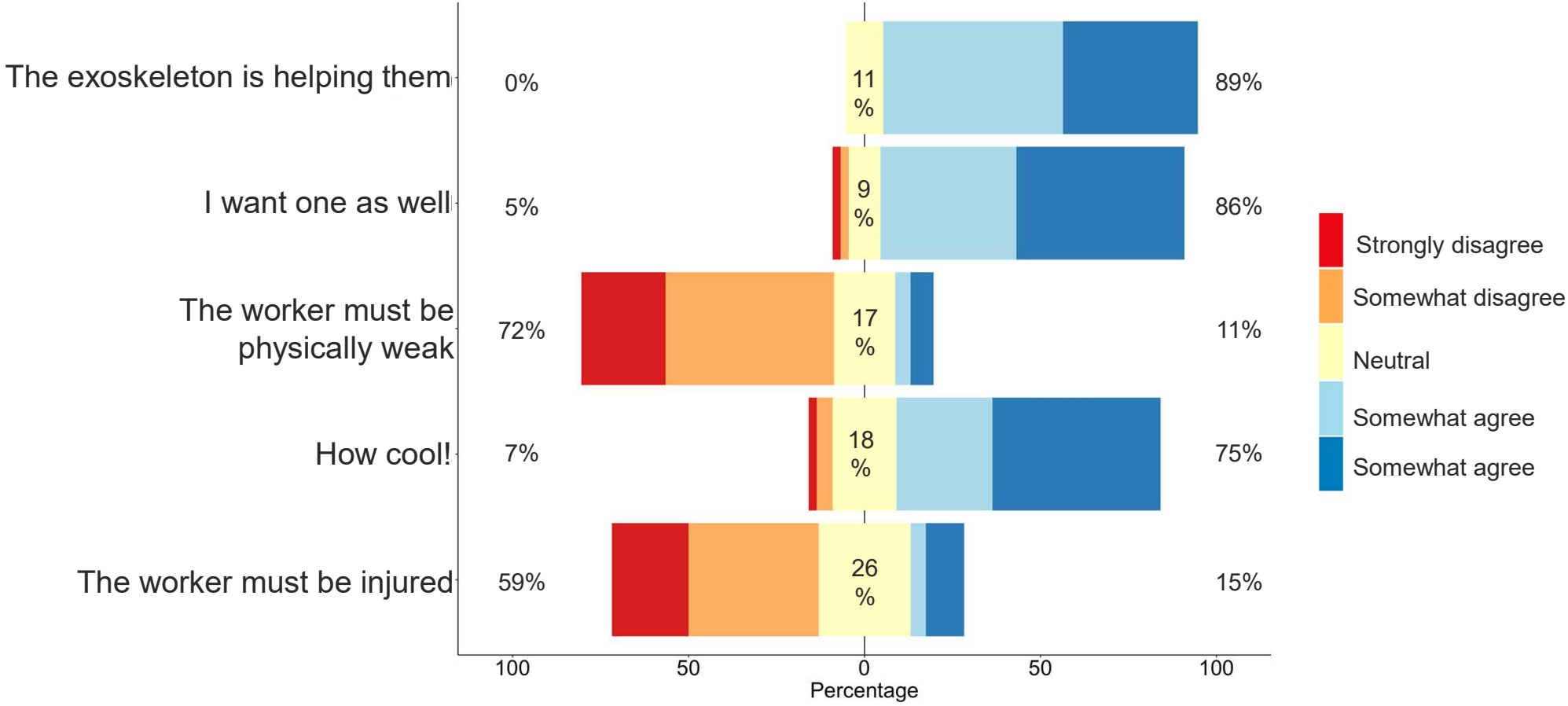
**Arm-support EXO**




**Back-support EXO**



# IF YOU SAW SOMEONE WEARING AN EXOSKELETON, HOW STRONGLY WOULD YOU AGREE OR DISAGREE WITH …



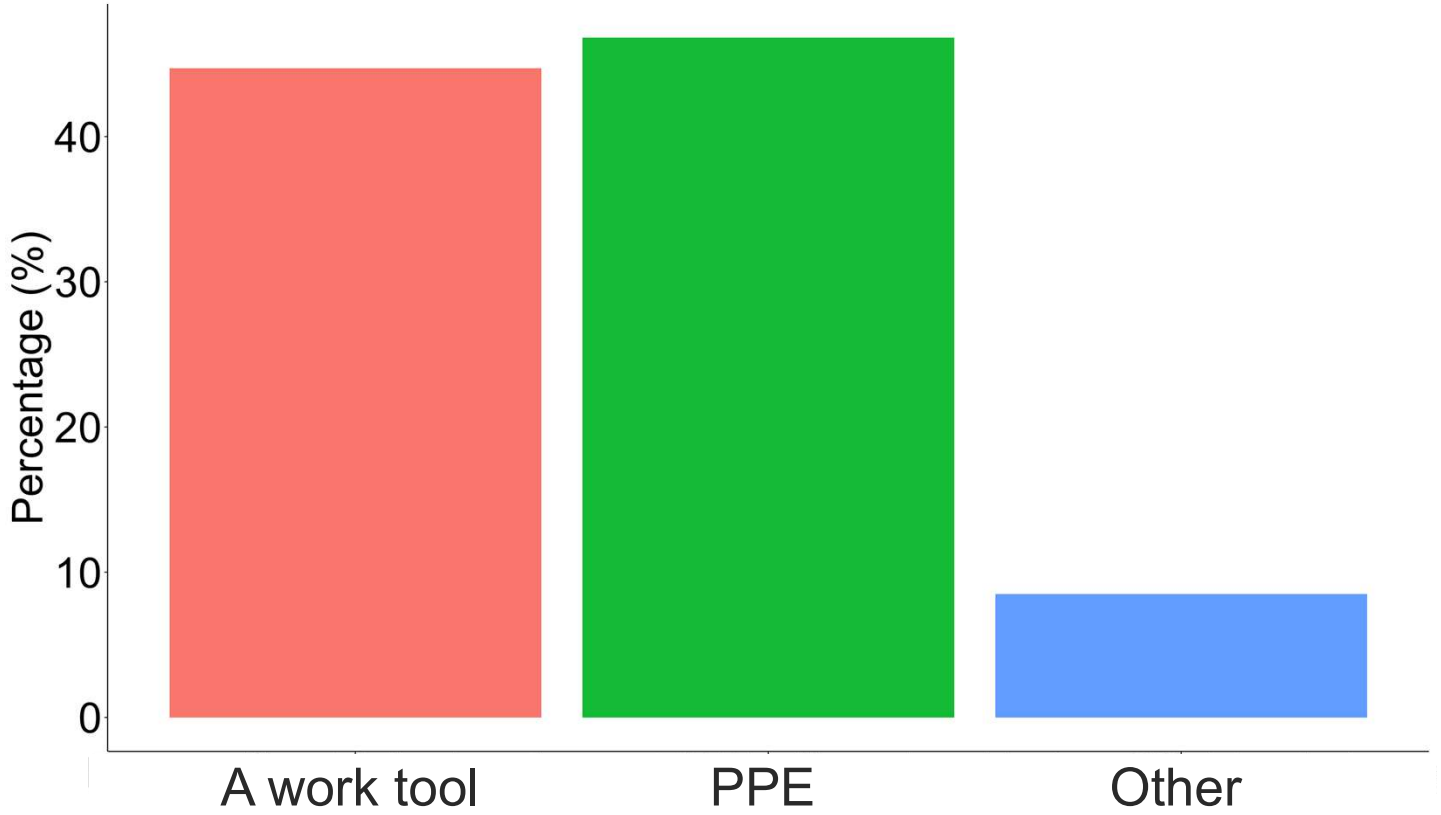
**How much do you think is an employer willing to pay?**

**$200 – $20,000**

How much do you think is a worker willing to pay?

**$100 – $5,000**

# IS AN EXO A WORK TOOL OR PERSONAL PROTECTIVE EQUIPMENT?



# EXOS IN MINING – MORE INFORMATION IS NEEDED

- **Understand users' opinions, concerns and opinions regarding EXO use**
- **Assess the effects of using an EXO in mining**
  - Different EXO types and designs
  - Mining-specific tasks
- **Develop mining-specific guidelines for safe & effective selection, adoption, and use**

We are actively seeking worker (survey) and operations and engineering participation (expert focus groups)

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