National Aeronautics and Space Administration

Suited ergonomic risk factors and considerations

Anthropometry and Biomechanics Facility

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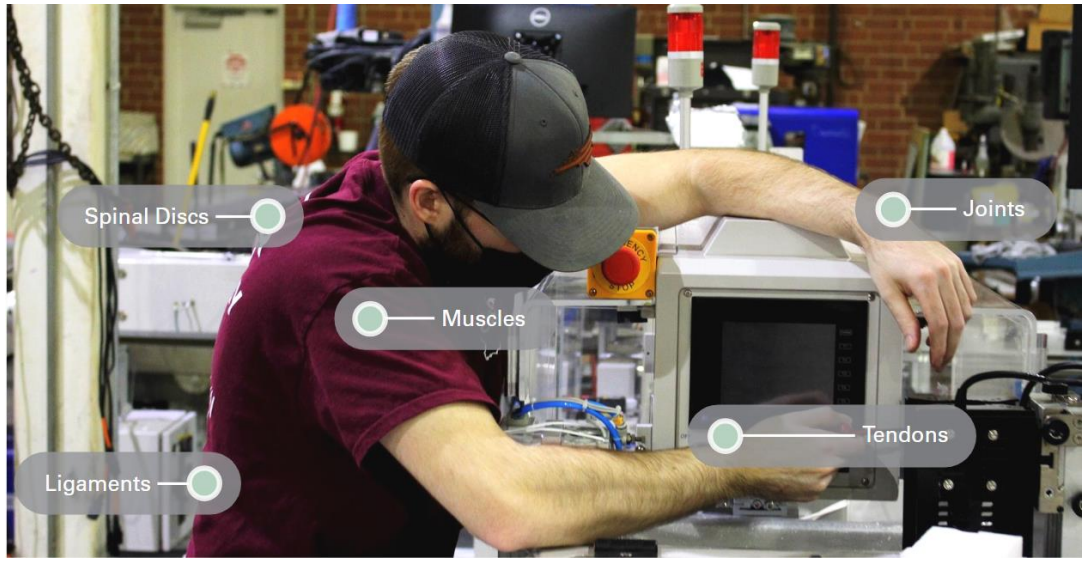
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Occupational musculoskeletal disorders

- Musculoskeletal disorders (MSDs) are injuries that effect the soft tissue of the body, such as muscles, tendons, ligaments, cartilage, nerves, and blood vessels
  - Examples: sprains, strains, tears, tendonitis, back injury/pain

- Ergonomic stressors related to posture, force, and repetition that have been proven to increase the risk for musculoskeletal injuries across various industries
  - Many jobs may have multiple ergonomic risk factors
  - Can lead to cumulative and chronic trauma

- Level of risk depends on:
  - Intensity
  - Frequency
  - Duration



Ergonomic risk factors



Image Source: www.osha.gov

Prolonged static positions

- Holding a fixed posture for a long duration
  - Examples: Sitting at a computer, standing at a production line
- Can cause:
  - Stresses/strains in muscles and joints, even if forces are low
  - Compression of tendons, blood vessels, and nerves
  - Muscle fatigue from lack of blood flow

Awkward postures

- Deviation from neutral posture, toward extremes of range of motion
  - Examples: bending, reaching, kneeling, squatting or twisting
- Can cause:
  - Increased stress to be applied to muscles, tendons, nerves, and bones
  - Higher exertion to produce the same force

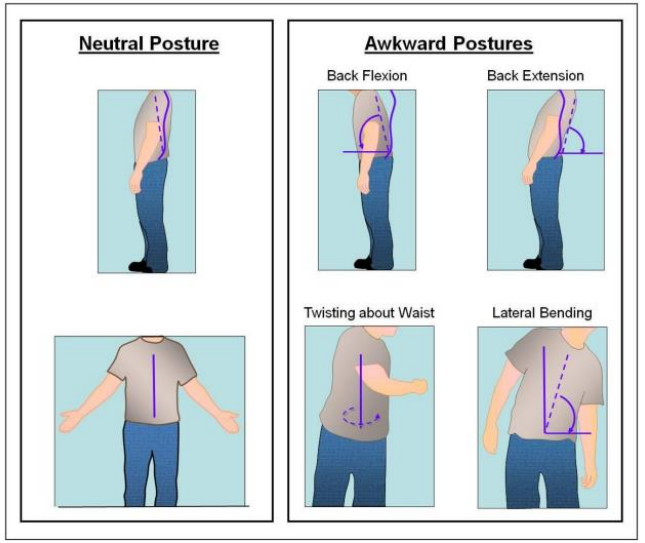


Image Source: Practical Demonstrations of Ergonomic Principles (NIOSH, 2011)

Ergonomic risk factors

<u>Forceful exertions</u>

- Producing a high level of force repeatedly, for a long duration, or in an awkward posture
  - Examples: heavy lifting, pushing, pulling, carrying, gripping
- Can lead to damage to muscles and related joints/tendons



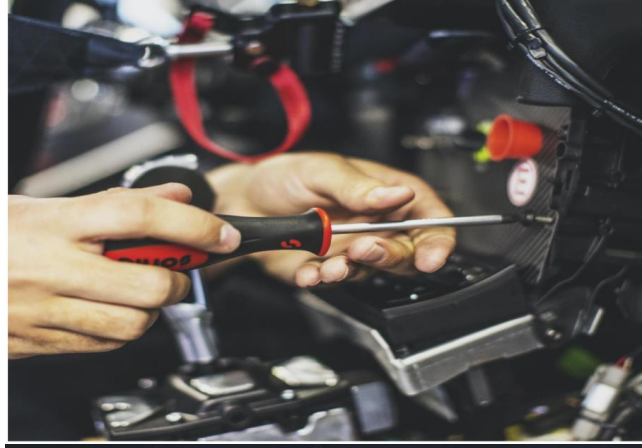
Image Source: www.osha.gov

<u>Contact stresses</u>

- Localized pressure exerted against the body by an external force (i.e. with a hard surface or edge)
  - Examples: resting forearms on desk edge, skin irritation
- Can compress and damage muscles, nerves, and blood vessels
  - Injury is most likely to occur in parts of the body with the least amount of protective tissue (fat and muscle)



Ergonomic risk factors







Repetition

- Performing the same motion over and over, high frequency tasks
  - Examples: repetitive lifting, assembly work, typing and mouse use
- Can lead to fatigue, stress overload, and tissue damage
  - Risk increases when there is not enough rest/recovery time

Extreme temperatures

- Working in an environment that is too hot or too cold
  - Example: Construction work (road and roofing), Steel mills
- Cold environments can reduce sensory feedback, dexterity, blood flow, and strength and can lead to increased muscle strains and pulls.
- Hot environments can increase fatigue and reduce strength.

Vibration

- Exposure to localized or whole-body vibration
  - Examples: Using hand-held power tools, driving earth moving machines
- Can cause pain, disfunction of nerves, loss of blood flow, and fatigue

Risk management strategies

- Engineering controls
  - Workstation layout
  - Tool design
  - Process design

- Administrative controls
  - Best work practices and techniques training
  - Task requirements, such as load limits
  - Ergonomic awareness programs
  - Job rotation and work schedules

- Personal protective equipment (PPE)
  - Ex: knee pads, footwear, gloves

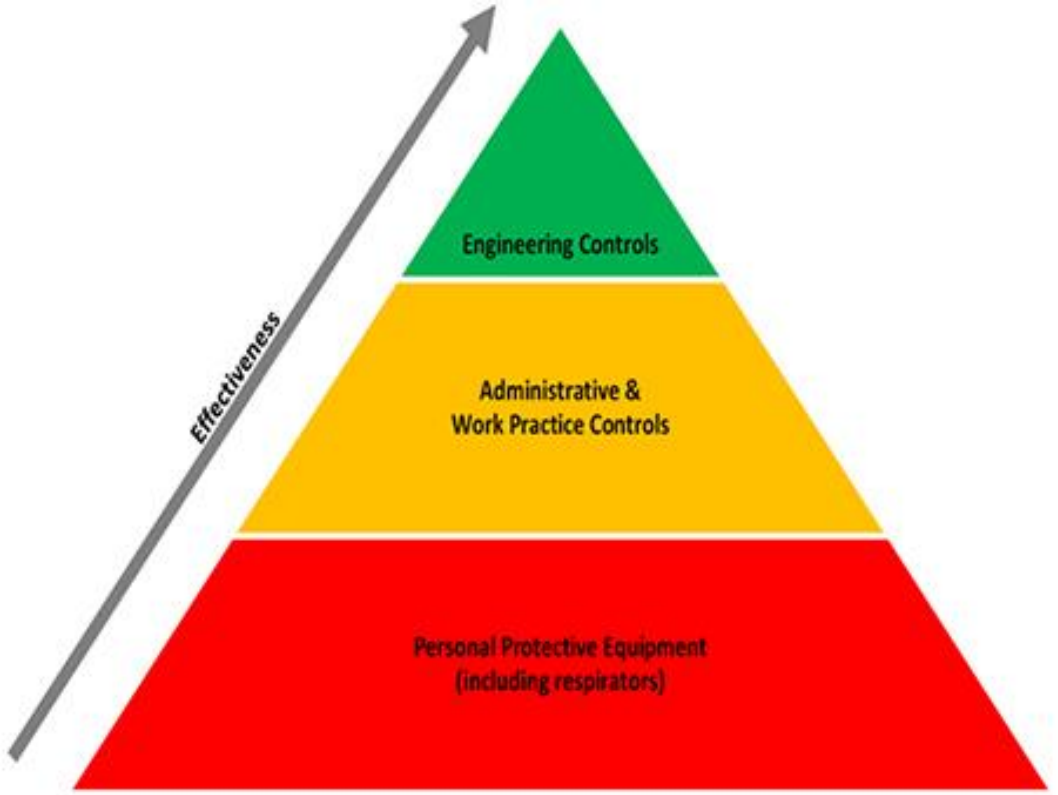


Image Source: www.osha.gov

Suited ergonomics: introduction

- During lunar EVA training and missions, crewmembers are expected to perform a variety of manual materials handling and geology tasks
  - Individuals must often lift, stoop, kneel, twist, grip, stretch, reach overhead, or work in other extreme positions, which can put them at risk of developing MSDs

- Tasks will be performed in a spacesuit that can compound ergonomic risk factors by:
  - Reducing range of motion that alters movement strategies
  - Introduce suit-to-human contact and interferences
  - Increasing strength demands by adding mass and bulk



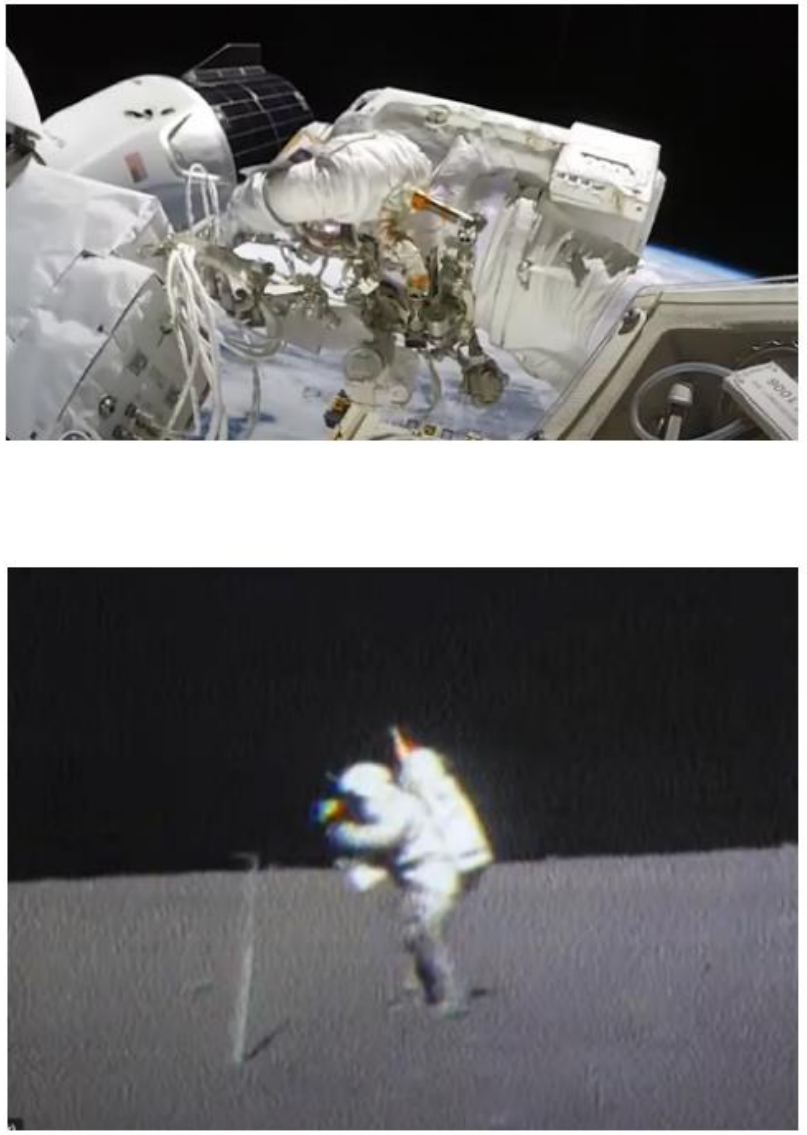
Suited ergonomics: overview

- As a result of operating in the suit and performing demanding EVA tasks, suited ergonomic injury mechanisms and risk factors can differ greatly from traditional unsuited ergonomics

- The ABF has a long history of studying the suited ergonomics of the EMU suit during ISS operations and is involved with researching the suited ergonomics of planetary suits

- Insights on suited ergonomic risk factors were derived from observational analyses, human performance testing, biomechanical modeling, and SME/test subject feedback

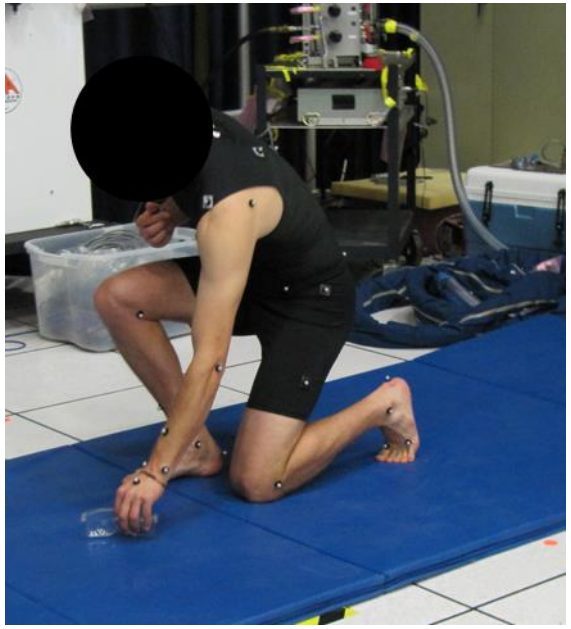
- The following slides will describe how ergonomic risk factors will differ while perform suited activities during lunar EVA training and missions

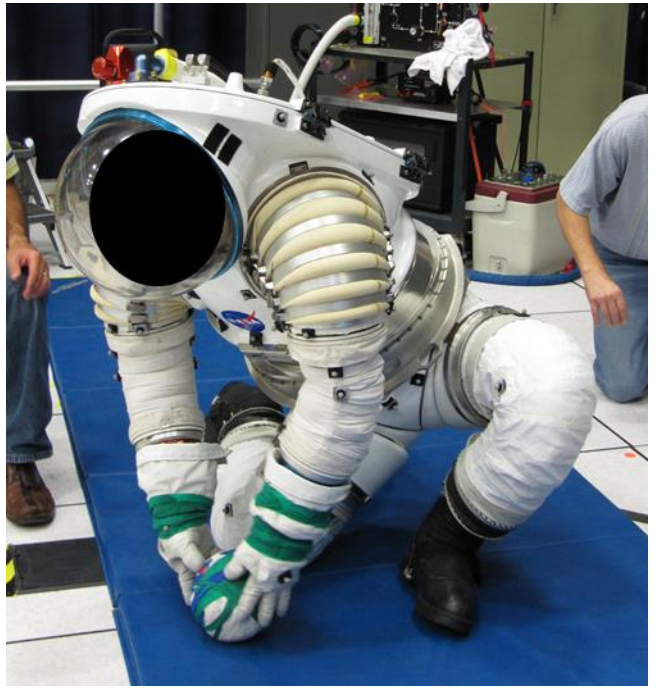


Examples of microgravity EVAs tasks (top) and Apollo lunar EVA tasks (bottom). Video credit: NASA

Suited ergonomics: working postures

- Due to the physical constraints imposed by suit architecture on the human, suited motion is dissimilar to natural human movement
- The spacesuit requires specific movement patterns and precise body positioning to perform functional lunar EVA tasks such as object pick up from ground
- The one-knee kneeling posture is a frequently used to perform surface/ground level work
- It is also common to see some level of trunk flexion, hip flexion, and hip abduction being used during various EVA tasks
- Elevated shoulder postures can be observed during some tasks, although it is not as common as during microgravity EVA





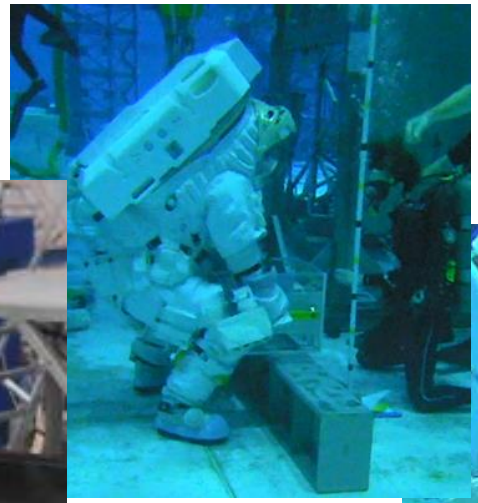
Suited ergonomics: working postures (cont.)

- Working postures are heavily dependent on anthropometry, tool design and worksite layout
  - There are several different ways to approach and complete a task

- Majority of EVA tasks involved back bending, kneeling, or a combination of both, which could result in higher lower extremity stresses








Suited ergonomics: prolonged static positions

- At 1/6 offloading conditions, sustained loads imparted on the body from the suit will be lower
  - Dependent on test analog environment

- However, the spacesuit PLSS will add a lot of mass that is aft of the body, which makes managing mass/moment more challenging and will affect neutral postures

- It is also anticipated that prolonged gripping (e.g., during extended carrying tasks) can result in higher risk of hand musculoskeletal stresses







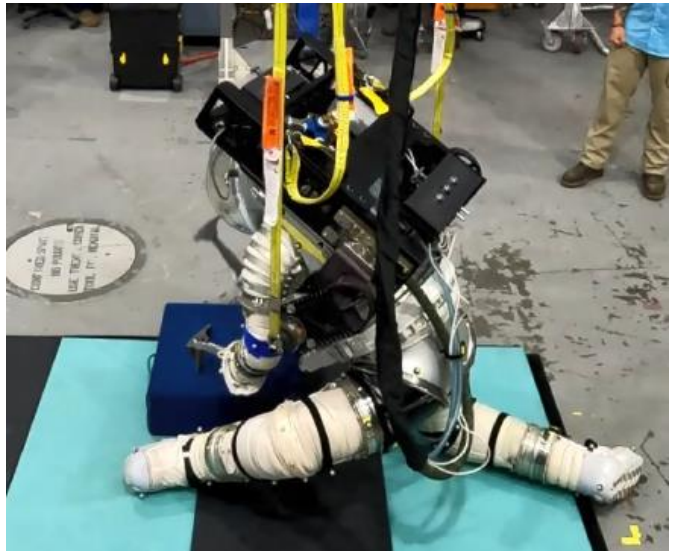
Suited ergonomics: forceful exertions

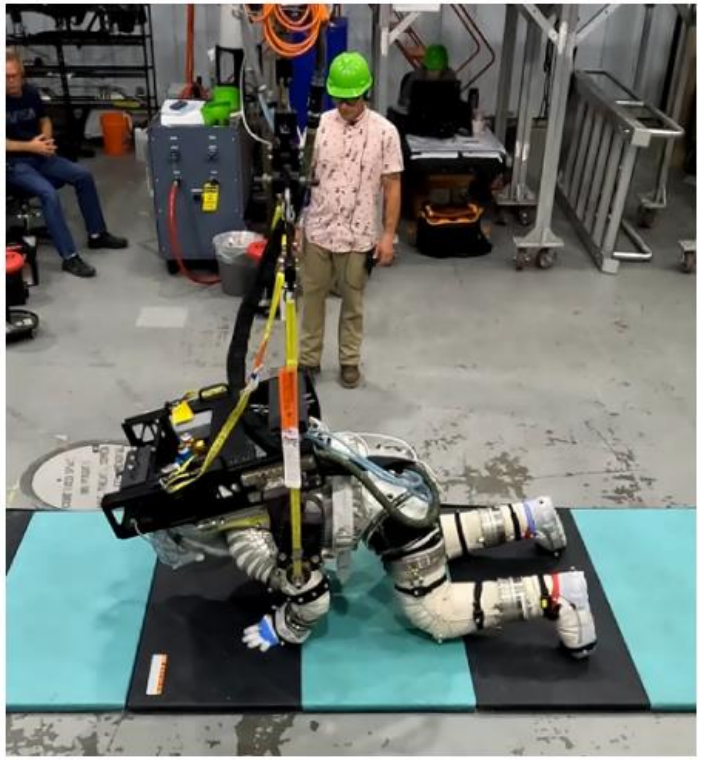
- Despite the 1/6g offloading, the mass inertial properties and stiffness caused by pressurization of the suit will lead to an overall increase of strength demands across the body to move in the suit

- Pressurization does not greatly inhibit elbow and knee flexion, but will significantly decrease hand grasp forces and dexterity

- Tasks will require forceful exertions from different body segments:
  - Prone recovery will require shoulder exertions, single-kneel recovery will require knee/ankle exertions, and most geology tasks will require upper body exertions

- There are other considerations (e.g., suit center of gravity, external suit hardware) that will affect a person's ability to gain biomechanical leverage

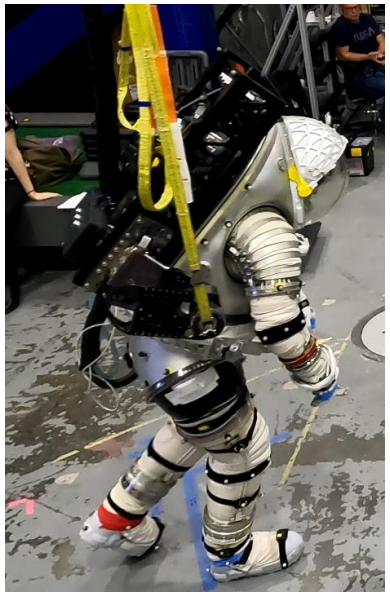




Suited ergonomics: contact stresses

- Physical interactions suit hardware and body can result in contact stresses such as chaffing or rubbing
- Padding is often introduced to improve suit fit indexing and reduce contact stresses
- However, suit contact stresses related to suited anthropometry and suit fit can still occur
- Suit contact patterns also change based on the task or simulation environment



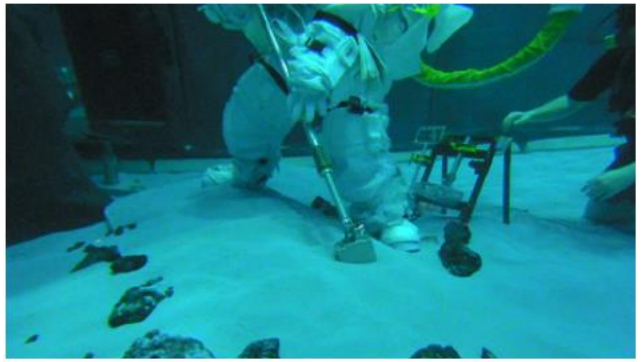


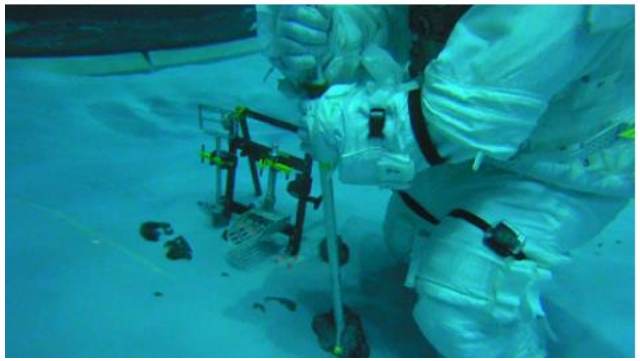


Suited ergonomics: repetition

- Due to the length of the EVA, there can be long periods of repeated movements and tasks
- Geology tasks can lead to highly repetitive movements of the hand and shoulder
- Tasks that involve greater force exertions such as carrying and repetitive lunging/kneeling tasks can quickly build fatigue and ergonomic stresses







Suited ergonomics: discussion

- The suited ergonomics will differ from conventional ergonomics thinking as the suit adds mobility limitations, human-suit interferences, and greater mass/inertia

- Therefore, suited ergonomic risk factors will be inherently different and vary with suited anthropometry, tool design, and worksite layout
  - Note: other environmental risk factors such as vibration and extreme temperatures have not been extensively studied for its effects on suited ergonomics

- It is important to minimize ergonomic stressors to reduce risk of MSD injuries by:
  - Taking into consideration the suit ergonomics during the EVA design and planning phase
  - Understanding how to approach a worksite, building experience in the suit, and achieving advantageous postures, which can mitigate effects from stressful and repetitive movements

Suited ergonomics work

Current

- Ergonomics task assessment model
  - Data-driven assessment to make comparisons between different suited techniques/movements
  - Populating a suited ergonomics data repository with biomechanical demands of EVA tasks (postures and joint moments)
  - Infusion of ergonomics model assessment and SME knowledge into EVA readiness and performance optimization training plan

Future

- Expand understanding of suited ergonomics with wider variety of anthropometry
  - Investigate if certain techniques provide greater biomechanical advantage for subjects with different body sizes
- Develop and implement evidence-based ergonomics training programs
- Assess crew-specific motion patterns
  - Provide individualized understanding of postural and suit fit related difficulties
  - Could inform specific training or countermeasures to optimize movement or reduce stresses