Joint-level biomechanics of high-intensity industrial tasks to inform exoskeletons for injury mitigation strategies

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Motivation

Occupational injuries in the lower back and knees are very common

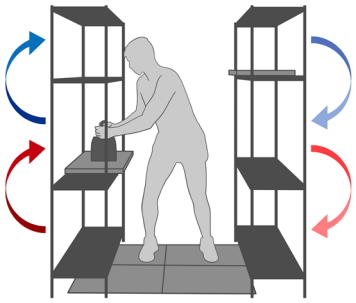
- Repetitive Twisting/Bending
- Asymmetric Lifting
- Pushing/Pulling
- Muscular Fatigue

Need to identify critical joint forces to inform exo assistance

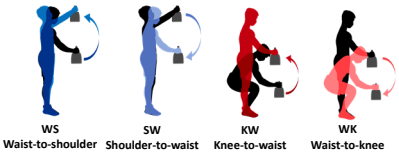
Heightened injury risk

⦸ Occupational injuries in 2020[1]
- ⦸ 62,540 back
- ⦸ 29,700 knee

Experimental Setup



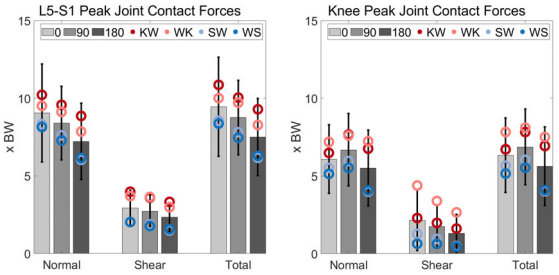
- 9 subjects
- Symmetrical v. asymmetrical lift turns (0°, 90°, 180°)
- 25 – lb. weight
- 4 start-end positions (WS, SW, KW, WK) → Right/Left



Data pipeline

Scaling → Inverse Kinematics → Inverse Dynamics → Muscle Analysis → EMG-Informed Solver → Joint Reaction Analysis

How are joint contact forces influenced by asymmetrical lifting?



- Symmetrical lifts (0°) generate higher joint contact forces.
- Internal joint demands are greater at the L5/S1 joint.

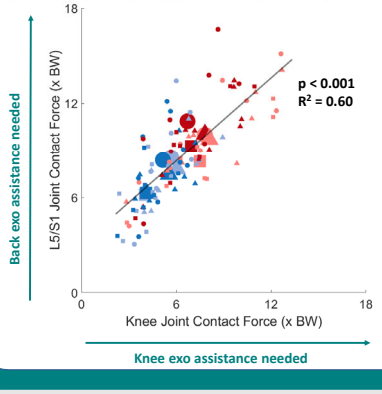
Remaining Question:
What is contributing to lower joint contact forces in asymmetrical lifting?

Key Takeaways

- **Symmetrical lifting elicits greater joint contact forces in the knee and the back.**
- **Lifting demands are proportionally distributed across knee and back joints.**
- **Asymmetrical lifting solicits sharing of muscle contributions to joint contact forces.**

Do the knee and the back share joint loading demands?

Relationship between L5/S1 and Knee Peak Contact Forces

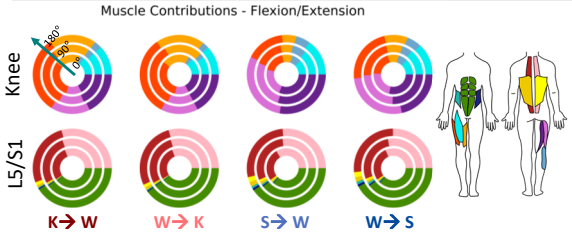


- Knee and L5/S1 joint scale relatively linearly independent of task.
- L5/S1 and knee contact forces are higher in below-waist lifting conditions.

Remaining Questions:
Will a back exo reduce L5/S1 contact forces in above-waist lifting ?
How will the prescription of a knee or back exo affect joint contact forces in below-waist lifting?

Which muscles contribute the most to joint contact forces in lifting?

Muscle Contributions - Flexion/Extension



Rings organized from symmetrical [0°] to asymmetrical [180°] lifting.
*** Area of ring or ring size is not indicator of greater contribution.*

Muscle involvement across each joint increases with asymmetry likely for joint stabilization.

Below-waist lifting KW - WK	Knee: Vastus medialis and vastus lateralis
	L5/S1: Erector spinae and rectus abdominis
Above-waist lifting WS - SW	Knee: Biceps femoris and semitendinosus
	L5/S1: Erector spinae and rectus abdominis

References

[1]Bureau of Labor Statistics. 2020 Survey of Occupational Injuries and Illnesses. Annual Report. Washington D.C. United States Department of Labor, 2021.

Acknowledgements

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