Hip-belt Load Sharing Reduces Peak Shoulder Pressure Across Walking Slopes During Heavy Load Carriage

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Objective

Quantify how pressure under backpack shoulder straps is affected by using a hip belt during heavy load carriage

Introduction

50% of active-duty military personnel experience a load-related musculoskeletal injury each year [1]

Heavy loads (30-40 kg) increase strain on upper-body nerves, reducing motor function and control of upper limbs and hands [2]

30% of vertical forces from backpack can be offloaded by a hip-belt attachment [3]

Little is currently known about the effect of using a hip belt on offloading shoulder strap pressure and the influence that walking slope has on shoulder pressure during load carriage.

U.S. Marine Corps photo by Cpl. Jeffrey Belovarac/Released

Methods

Participant Demographics

Military Service Personnel
N = 4 (3M,1F)
Height: 1.66 ± 0.05 m
Weight: 65.2 ± 9.0 kg
Age: 28 ± 6 y

2 Load Conditions

Hip Belt Assisted (Hip Belt)
- Body armor, helmet, and backpack
- 40% body weight total

Shoulder borne
- Body armor, helmet, and backpack
- 40% body weight total

Images: Courtesy of NHRC

3 Slope Conditions (treadmill walking, 1.15 m/s)

Icons: Noun Project

10° Downhill 0° Level 10° Uphill

Outcome metrics

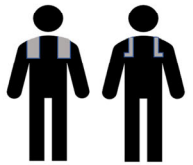
1. Peak Point Pressure
2. Average Total Pressure

Computed in MATLAB

Linear Mixed Effects

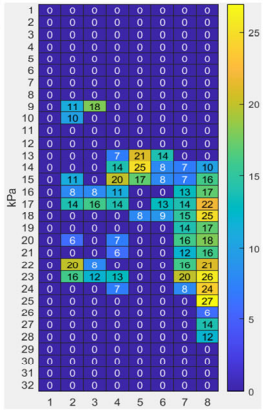
- Backpack, Slope, Backpack × Slope, participants as random intercepts
- ANOVA (α = 0.05), Pairwise comparisons using Tukey's HSD
- Analysis performed using R (R Core Team (2022). https://www.R-project.org/)

Pliance Sensor Orientation



Front View Back View

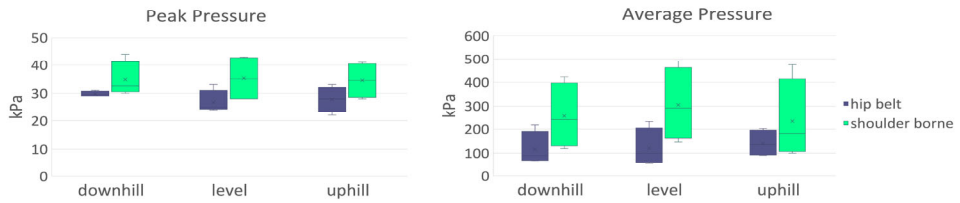
- Pressure data from two Pliance® sensors (Novel, Inc) collected at 20Hz
- 256 sensing sites (1cm^2, 8x32 grid) from each sensor. Cells are arranged in an 8x32 grid and oriented lengthwise to align with shoulder straps



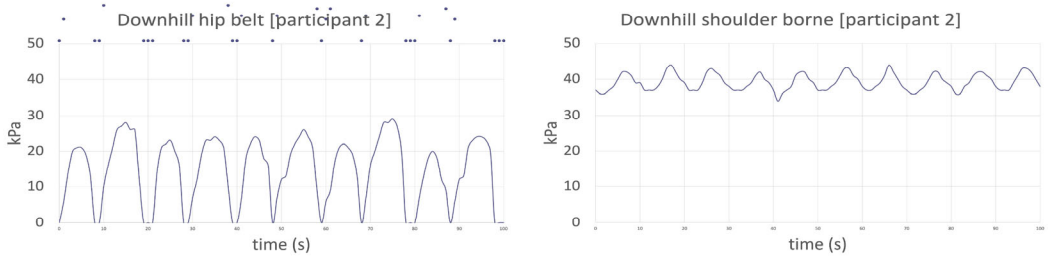
Visualization of pressure magnitude over sensor area

Results

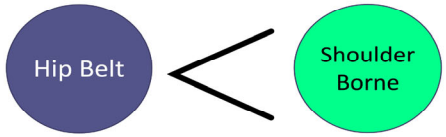
Average and Peak Pressure for all slope conditions (n=4)



Peak pressure over time between load conditions

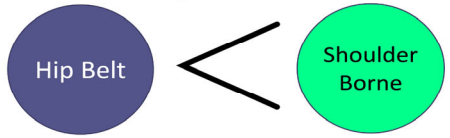


Peak Pressure
p = 0.004



25.9% decrease

Average Pressure
p = 0.001



120.7% decrease

Conclusions

- **Hip-belt configuration effectively reduced peak and average shoulder pressure in all participants under all slope conditions.**
- **Both shoulder and hip-belt conditions resulted in peak pressure below the recommended maximum, 45 kPa [4].**
- **Lower peak and greater range of pressure occurred when participants wore hip belt, resulting in a decrease in average pressure on all slopes.**
- **Future work will examine asymmetry between shoulders and analyze relationship between load condition and backpack kinematics.**

Acknowledgments

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References

[1] U.S. Army Public Health Center (2018)
[2] Hadid et al. (2015) *J Biomech*, 48(15)
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[4] Bryant et al. (2004) *Ergon Des*, 12(Winter)