Males Produce More Lower Limb Work than Females during Loaded Vertical Jumps
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Summary
This study sought to determine the impact of body borne load on performance and lower limb biomechanics during a vertical jump, and whether they differed between sexes. 20 males and 17 females completed three vertical jumps with four loads (20, 25, 30, 35 kg). Load decreased vertical jump performance for all participants, but males performed better than females with load. Males performance may be attributed to the increased limb, and hip, knee and ankle work they produced during the jump compared to the smaller and weaker females.

Introduction
Military personnel routinely run, jump and land with heavy body borne load (greater than 20 kg) [1]. Performing these tasks with heavy load is necessary for operational success, but reportedly decreases physical performance and increases injury risk, particularly for females [2]. Vertical jump is a common operational task that quantifies physical performance, including individual power, strength and speed. During a loaded vertical jump, performance (jump height) may be impacted by alterations in lower limb and joint work and power, and the subsequent ability to increase center of mass take-off velocity (COM). While there is a reported sex dimorphism in athletic tasks [3], it is unclear if both sexes adapt similarly to adding military-relevant load during a vertical jump task. We hypothesized that body borne load would reduce vertical jump performance for all participants, but the smaller females would exhibit a larger reduction in performance because of a decreased ability to produce lower limb work compared to males.

Methods
20 males and 17 females (73.81 ± 11.55 kg, 1.73 ± 0.08 m, 21.31 ± 5.69 years) had lower limb biomechanics quantified during three vertical jumps with each body borne load (20, 25, 30 and 35 kg). For the vertical jump, participants started in athletic position, with feet shoulder width apart on side-by-side force platforms, and bend down into a squatting position before performing a maximal effort vertical jump. During each jump, lower limb biomechanics were quantified from 34 retroreflective makers. The synchronous GRF data and marker trajectories were lowpass filtered with a fourth-order Butterworth filter (12 Hz) and then, joint rotations and kinetics were solved in Visual 3D (C-Motion, Rockville, MD).

For analysis, jump height (m), COMv (m/s), total limb work (J/kg), and hip, knee and ankle joint work (J/kg) of the dominant limb were quantified from onset of propulsion phase (vGRF greater than body weight plus load) to take off. Each variable was submitted to a RM ANOVA to test the main effects and interaction between load (20, 25, 30, 35 kg) and sex (male, female). Where statistically significant (p<0.05) interactions were observed, simple main effects analysis was conducted, and a Bonferroni correction was used for all pairwise comparisons.

Results and Discussion
Body borne load decreased jump height (p=0.001) and COMv (p=0.001) for all participants. But, males had 8% higher jump (0.25 vs 0.14 m; p<0.001) and 33% higher COMv than females (1.4 vs 1.9 m/s; p<0.001). The impact of load on COMv was dependant on sex (p=0.046). Males exhibited greater COMv than females 20, 25 and 35 kg (p<0.006) loads. However, males exhibited a significant 15% reduction of COMv when adding load (p<0.019), while females did not exhibit a similar reduction in COMv with load.

Male’s jump performance may be attributed to their ability to produce greater total limb work than females (p<0.001) (Fig 1). Males also produced greater positive work at the hip (1.1 vs 0.8 J/kg; p<0.001), knee (1.5 vs 1.1 J/kg; p<0.001), and ankle (1.1 vs 1.0 J/kg; p<0.001) compared to females. The smaller, weaker females may not possess the strength to produce similar lower limb work as males when encumbered by load during the vertical jump. Although body borne load had a significant effect on jump performance, only ankle work was impacted by load (p<0.001). Participants increased ankle work with the 35 compared to 20 (p<0.001) and 25 kg (p=0.001) loads. Future work is needed to determine the specific military conditioning protocols to improve operational performance, particularly in females.

Figure 1: Joint contribution (J/kg) to total limb work (J/kg) in males and females for each load configuration.

Conclusions
Body borne load decreased vertical jump performance for all participants. But, males exhibited greater performance than their female counterparts. Male’s better performance may be attributed increased limb, and hip, knee and ankle work they produced with load compared the smaller, weaker females. To improve operational performance, military conditioning protocols ought to increase female lower limb strength.

References