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Sex Impacts Leg Stiffness When Increasing Stride Length to Run with Body Borne Load

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Abstract

Military personnel routinely run at a fixed cadence with body borne load, which may increase leg stiffness and potential injury risk - particularly for females. Seventeen males and ten females had leg stiffness quantified when running with four loads (20, 25, 30, and 35 kg) and three stride lengths (preferred, and ±15% of preferred). Participants increased leg stiffness (*P*=0.006), and potentially injury risk when running with load. But, a sex dimorphism in stiffness was evident with changes in stride length. Males exhibited reduced leg stiffness with longer strides (*P*>0.05).

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INTRODUCTION

During military activities, personnel often run at a fixed cadence with heavy body borne loads weighing between 20 and 40 kg. These loads can increase injury risk by altering lower limb biomechanics [1].

When running with load, personnel increase leg stiffness to attenuate larger ground reaction forces (**vGRF**) and prevent collapse of the lower limb, elevating risk of musculoskeletal injury (**MSI**) [2]. During unloaded running, individuals decrease leg stiffness when using longer strides [3]. Military personnel, however, may not possess the lower limb strength to similarly decrease leg stiffness as they lengthen their stride to run at a fixed cadence with heavy body borne loads.

Female military personnel, who are weaker than males [4], may be especially at risk for injury as they may lack the strength to safely attenuate large GRFs.

PURPOSE

To quantify leg stiffness for male and female participants as they lengthened their stride to run with body borne load.

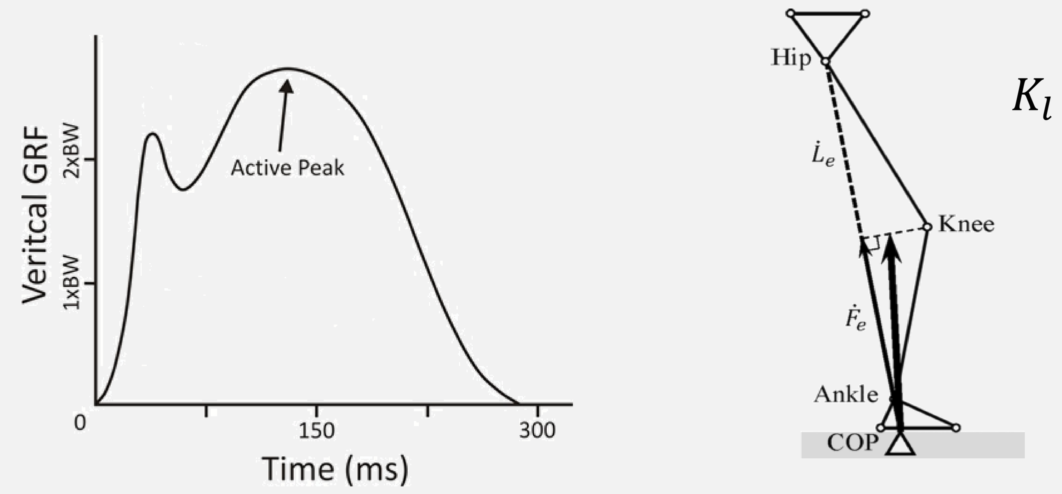
METHODS

27 (17 M/ 10 F) participants (21.2 ± 2.3 years, 1.7 ± 0.1 m, 75.5 ± 11.3 kg) had 3D lower limb biomechanics quantified while running with four body borne loads: 20 kg, 25 kg, 30 kg and 35 kg (**Fig 1**.).

Figure 1: For each load condition, participants were outfitted with a helmet, weighted vest, and mock weapon. The weight of the vest was adjusted to within 2% of the target load (20 kg, 25 kg, 30 kg, or 35 kg) for that session.

For the run task, participants ran at 4 m/s (± 5%) and used one of three stride lengths: preferred stride length (**PSL**), 15% shorter (**SSL**) and 15% longer than PSL (**LSL**). Participants performed three successful trials at each stride length.

METHODS



$$K_l = \frac{F_e}{\max(\Delta L_e)}$$

Figure 2: During each run task, participants had lower limb biomechanics, including peak vGRF (A) and leg stiffness (B) quantified. Leg stiffness (K_l) was calculated as the GRF vector directed from the center of pressure through the hip joint center (F_e) divided by the maximum change in leg length (L_e).

Peak of stance (**PS**, 0%-100%) leg stiffness, vGRF, change in leg length, and hip, knee and ankle flexion angles were submitted to a RM ANOVA to test the main effect and interaction between load (*20 kg, 25 kg, 30 kg, 35 kg*), stride length (*PSL, SSL, LSL*), and sex (*Male, Female*). Significant interactions were submitted to a simple effects analysis, and a Bonferroni correction was used for pairwise comparisons. Alpha was p < 0.05.

RESULTS

Both body borne load (*P*<0.001) and stride length (*P*<0.001) had a significant effect on peak vGRF (Fig. 3).

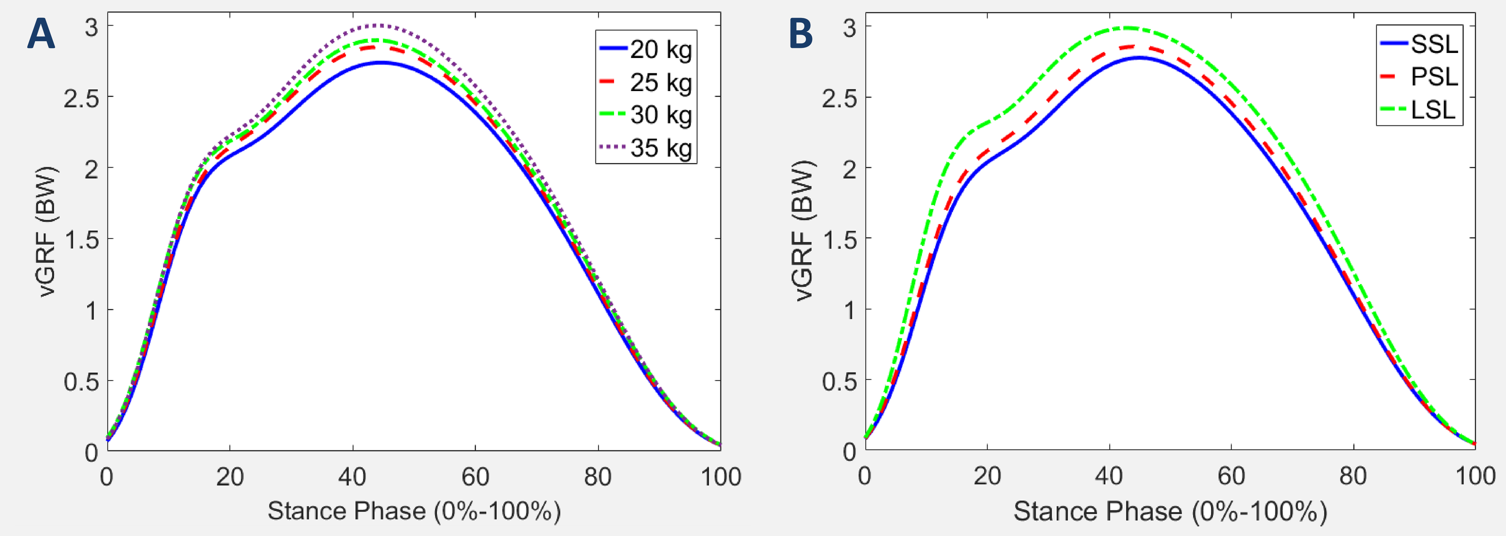


Figure 3: Stance phase (0%-100%) vGRF exhibited with each body borne load (**A**) and stride length (**B**).

The addition of body borne load increased leg stiffness up to 12% (*P*=0.002). But, males decreased leg stiffness with LSL compared to PSL and SSL (*P*<0.001; *P*<0.001), and PSL compared to SSL (*P*=0.026); whereas, females exhibited no difference in leg stiffness between strides (*P*>0.05) (Fig. 4).

ACKNOWLEDGEMENTS

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RESULTS

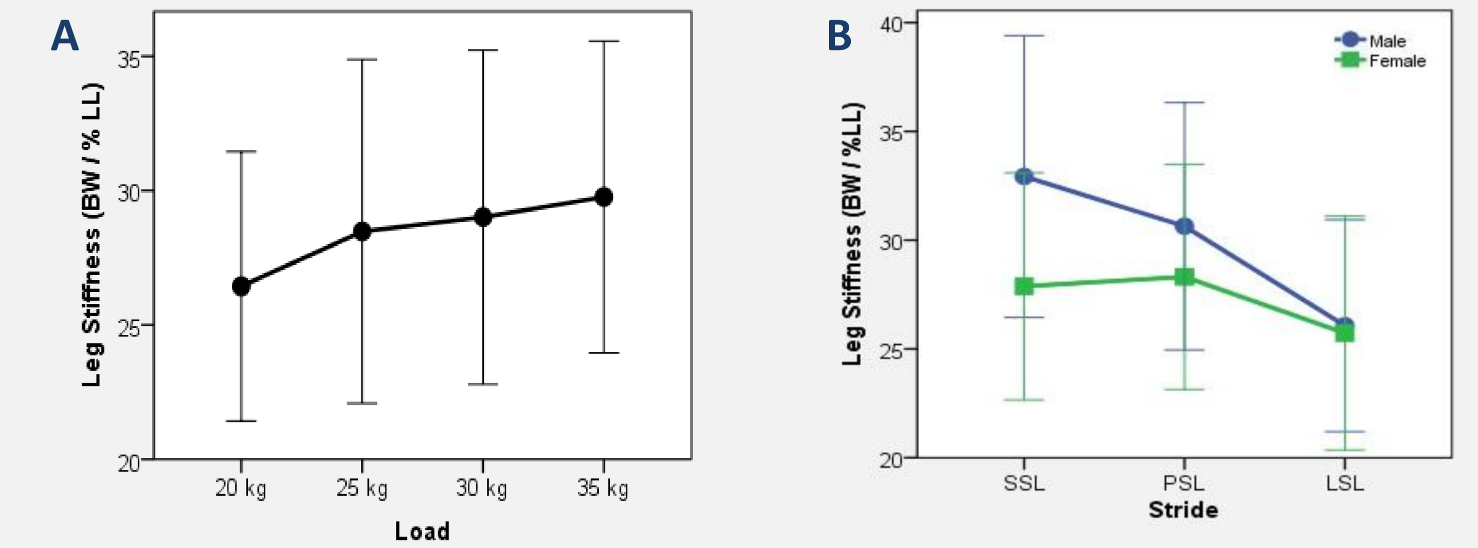

Figure 4: Mean (±SD) leg stiffness exhibited by participants with each body borne load (**A**) and by males and females when using each stride length (**B**).

Females adopted greater PS hip (*P*=0.013) and knee flexion (*P*=0.001) compared to males with SSL. But, only male increased PS hip and knee flexion as stride length increased from SSL to PSL (*P*=0.008; *P*=0.001) and from PSL to LSL (*P*=0.041; *P*<0.001) (Fig. 5).

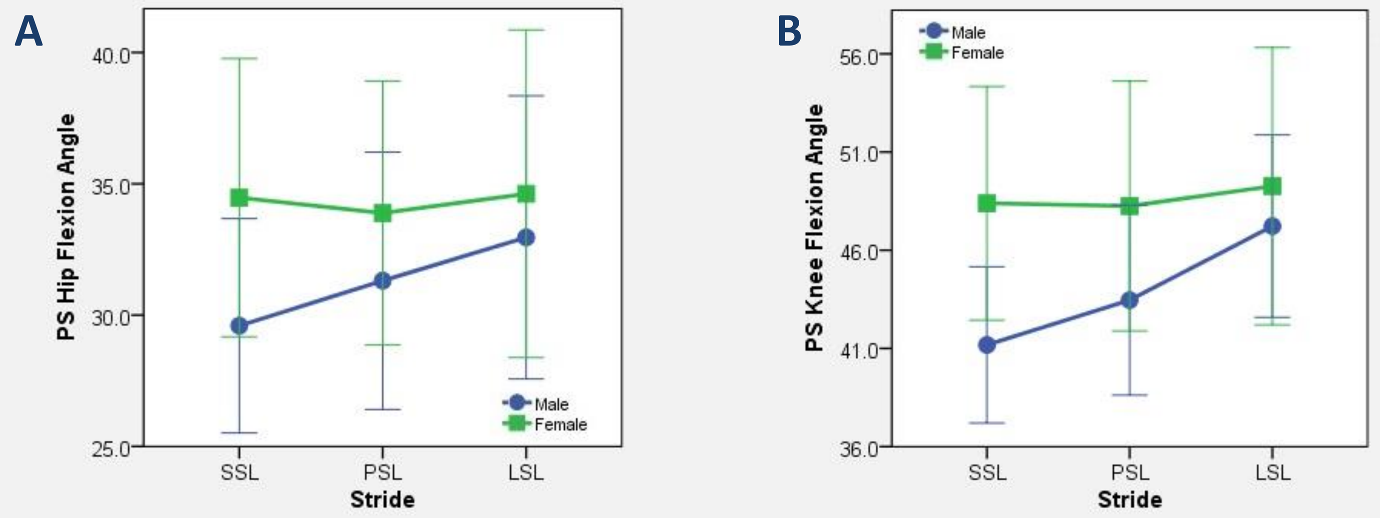

Figure 5: Mean (±SD) PS hip (**A**) and knee (**B**) flexion angle exhibited by males and females when running with each stride length.

Participants increased PS knee flexion angle with LSL compared to PSL when carrying the 20 (*P*<0.001), 25 (*P*<0.001), and 30 kg loads (*P*=0.004), but not 35 kg (*P*=0.760).

CONCLUSION

Participants increased leg stiffness to prevent lower limb collapse and attenuate the increase in vGRF observed with the addition of load. Males, but not females, reduced leg stiffness by increasing hip and knee flexion when running with longer strides. Further study is warranted to determine of lower limb strength, rather than sex, determines the ability to adjust leg stiffness when altering stride length during loaded running.

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