The Effect of Biological Sex, Load and Operational Walking Speeds on Lower-Limb Coupling Variability

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Summary

Load-carriage injuries are prevalent among military personnel. Examining military-relevant constraints on lower-limb coupling variability may reveal potential injury mechanisms. Lower-limb kinematics were collected from 23 Australian Army soldiers (12 males) across nine, 12-minute walking trials, at speeds of 3.5, 5.5, and 6.5 km·h^{-1} and loads of 7.2, 23.2, and 35.2 kg. There were significant sex-load-speed interactions throughout the gait cycle. The sex differences in lower-limb coupling variability with load at operational walking speeds may explain mechanisms of military load-carriage injuries. Further research needs to explore whether changes in variability have a causal relationship with injury risk.

Introduction

Load carriage results in a high proportion of lower-extremity injuries in the military [1], with female personnel more likely to sustain a lower-extremity musculoskeletal injury than males [2]. Lower-limb coupling variability (CV) has been proposed as a mechanism of injury, with injured individuals demonstrating both higher and lower variability than healthy individuals [3,4]. Further, CV has been shown to increase with increases in load [5], decreases in walking speed [6] and differ between males and females [7]. This study aims to quantify the effects of biological sex, load and operational walking speed on lower-limb CV.

Methods

Twenty-three Australian Army soldiers (12 males) completed nine 12-minute walking trials at three speeds (3.5, 5.5, 6.5 km/h) and three loads (7.2, 23.2, 35.2 kg). Segment angles were calculated for the Pelvis, Thigh, Shank and Foot in the sagittal (SAG), frontal (FRO), and transverse (TRA) planes. Coupling variability was calculated using continuous relative phase standard deviation for nine couplings, averaged across initial, mid, and late stance, and terminal swing. Linear mixed-effect models determined interactions between load, speed and sex.

Results and Discussion

There were significant sex-load-speed interactions throughout the gait cycle for the PelvisFRO-ThighFRO, PelvisTRA-ThighFRO and ShankTRA-FootFRO couplings (Figure 1). The increases in CV at slower speeds for females may be the result of overstriding and widening the base of support [8]. The addition of overstriding while carrying load and maintaining walking speed was likely more challenging for the female cohort than the male cohort, contributing to reduced CV. The lower CV in the females compared with the males may provide one of many potential mechanisms of common military injuries. The ShankTRA-FootFRO coupling is suggested to play a role in force attenuation [9]. Thus, the lower CV in the female cohort may represent a reduced ability to attenuate force and therefore increase risk of injury.

Conclusions

The perturbation provided by increases in external loads and walking speeds, was likely more challenging for the female cohort as it resulted in reduced CV. The lower CV in the females compared with the males may provide one of many potential mechanisms of common military injuries.

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