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Foot Progression Angle Predicts Knee Adduction During Load Running

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FOOT PROGRESSION ANGLE PREDICTS KNEE ADDUCTION DURING LOAD RUNNING

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INTRODUCTION

Premature knee osteoarthritis (OA) is an increasing problem for military personnel, which may be attributed to the physical activity they routinely perform with body borne load.

Foot progression, such as toe-out or toe-in gait, may increase during locomotor activities, such as running, with body borne load and elevate military personnel's risk of knee OA. For instance, increasing toe-out reportedly increases knee adduction, specifically the knee adduction moment (KAM), biomechanics related to knee OA that is prevalent in military personnel.

Yet, it is currently unknown if the body borne load military personnel routinely carry during all operational and training exercises, such as running, increases either foot progression or knee adduction.

PURPOSE

To examine the effect of body borne load on foot progression angle and knee adduction biomechanics, and determine whether it differs between sexes when running with body borne load.

METHODS

Participants: 20 male and 16 female (**Table 1**).

Table 1. Subject demographics (N = 36).

Male	N	**Height** (m)	**Weight** (kg)	**Age** (years)
	20	1.79 ± 0.08	81.69 ± 9.42	21.33 ± 2.77
Female	16	1.66 ± 0.03	66.86 ± 8.18	21.92 ± 1.97

Conditions: Four body borne loads (20, 25, 30 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.

Run Task: Participants performed three successful run trials with each load, which they required they run at the correct speed (4 m/s ± 5%) and only contact the force platform with their dominant limb.

METHODS CONT'D

Biomechanical Analysis: Synchronous GRF data and 3D marker trajectories collected during each run were low-pass filtered (4th order butterworth, 12 Hz). Then, the filtered marker trajectories were processed to obtain 3D knee joint rotations and foot progression, and kinematic and GRF data submitted to inverse dynamics to calculate 3D knee joint moments using Visual 3D (C-Motion, Rockville, MD).

Dependent Variables: Foot progression angle (FPA) (**Fig. 2**), and knee abduction joint angle (KAA) and moment (KAM) were calculated across stance phase (0% - 100%).

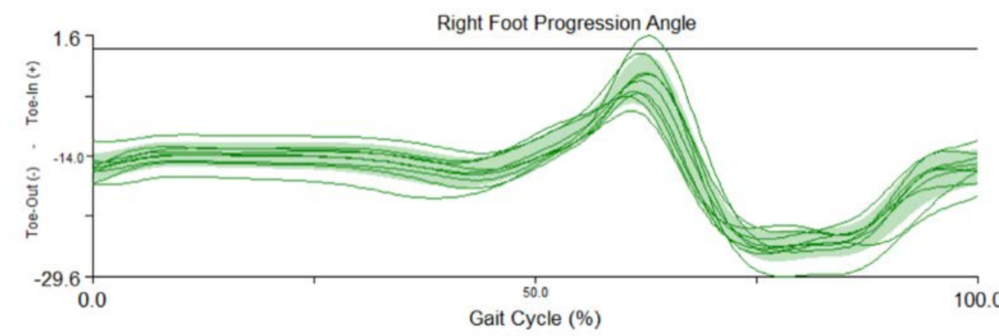

Figure 2. Foot Progression Angle, a measure of Toe-In or Toe-Out, was calculated with respective to direction of running during stance.

Statistical Analysis: FPA at initial contact (IC) and peak stance (PS) KAA and KAM were submitted to a linear model with load (20, 25, 30 and 35 kg) and sex (male, female) as fixed effects, and subject identity as random effect. Additionally, FPA was considered a covariate for KAA and KAM. Bonferroni procedure was used for multiple comparisons. Alpha was $p < 0.05$.

RESULTS

Sex ($p=0.046$), but not load ($p=0.261$) had significant effect on FPA at IC (**Table 2**). Specifically, males exhibited 3.5 degrees greater foot progression at IC than females during load running.

Table 2. FPA at initial contact for male and female participants with each body borne load.

Male	20 kg	35 kg	30 kg	35 kg
	-3.9	-2.8	-4.6	-3.6
Female	-1.5	1.6	1.1	2.1

Load and sex had a significant effect on PS KAM ($p=0.037$; $p=0.013$), but not PS KAA ($p=0.111$; $p=0.681$) (**Table 3, Fig. 4**). Peak KAM was greater for the 35 kg compared 20 kg load ($p=0.029$), but similar differences were not observed between any other load ($p>0.05$). Males exhibited greater 0.16 Nm/kgm PS KAM than females.

Table 3. PS knee adduction moment for male and female participants with each body borne load.

Male	20 kg	35 kg	30 kg	35 kg
	-0.7	-0.8	-0.7	-0.8
Female	-0.5	-0.6	-0.6	-0.6

RESULTS CONT'D

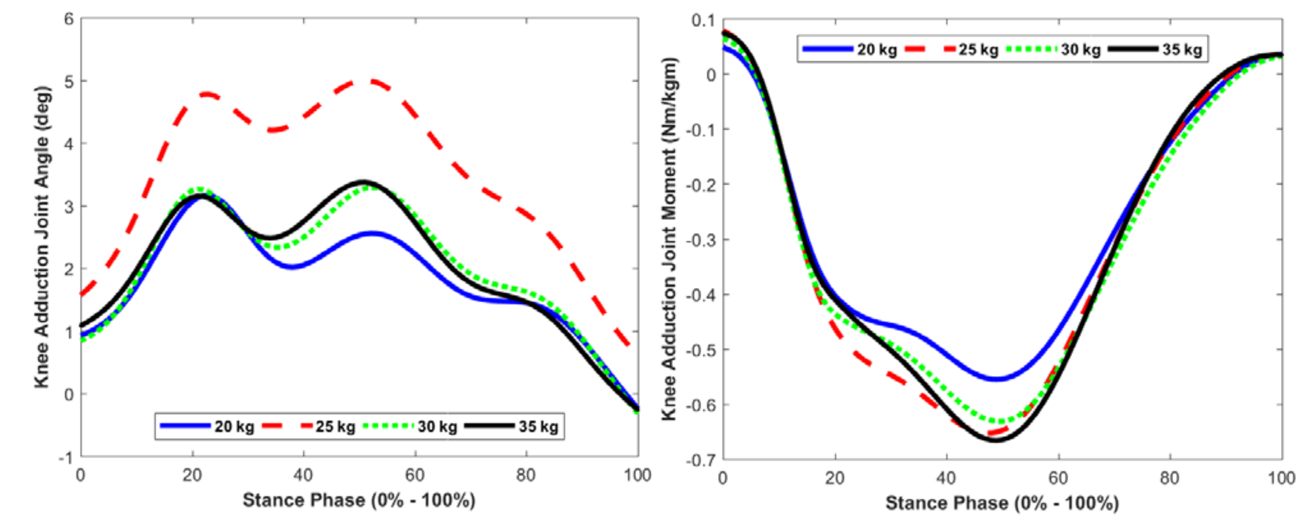

Figure 4. Mean stance phase (0% - 100%) knee adduction angle (A) and moment (**B**) with each body borne load.

FPA at IC was a significant covariate for both PS KAM ($p=0.003$) and KAA ($p<0.001$) (**Fig. 5**). For each 1 degree in IC foot progression, participants exhibited 0.01 Nm/kgm increase in PS KAM and 0.2 degree increase in PS KAA, respectively.

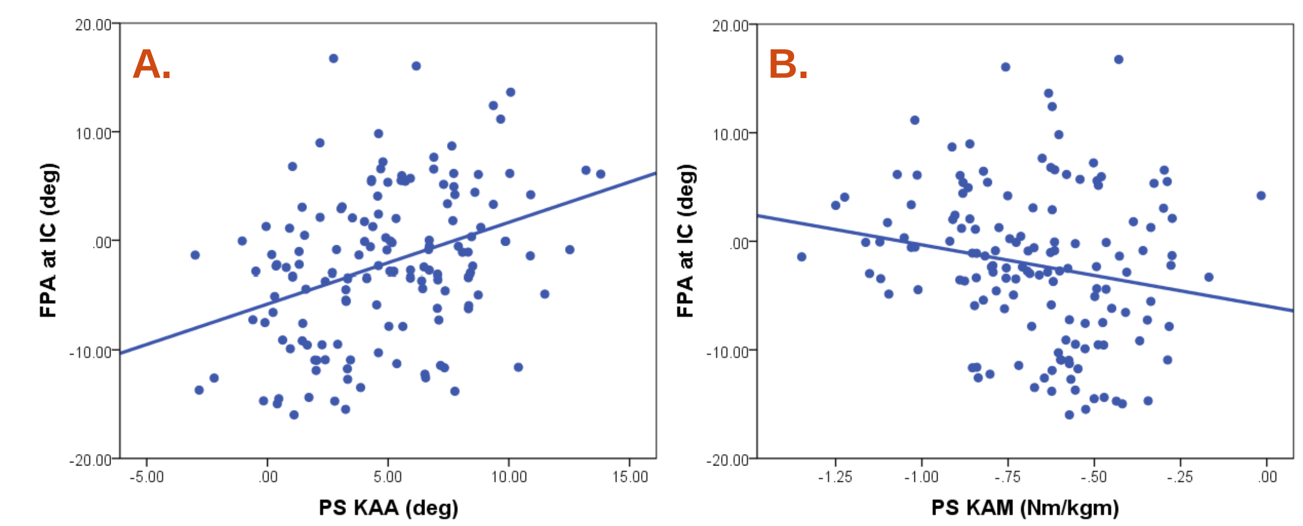

Figure 5. Depicts relation between FPA at initial contact and knee adduction angle (**A**) and moment (**B**).

CONCLUSION

Males may be at greater risk of knee OA, as they exhibited 3.5 degrees greater FPA and 0.16 Nm/kgm greater KAM than females. But, the military may decrease risk of knee OA, particularly for males, by modifying foot progression during training programs.

ACKNOWLEDGMENTS

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2. Wang et al. Human Move Sci, *64*, 213–220, 2019.