Evaluation of Ankle Range of Motion and Dynamic Stiffness for Human Foot-Ankle Surrogate Design

Wake Forest® School of Medicine

Wake Forest® Baptist Health

Julia-Grace Polich, Michael B. Tegtmeyer, John H Bolte IV, Aaron Scott, MD, Paula Gangopadhyay, DPM, Per Kristian Moerk, DPT, and Kerry A. Danelson

Background

Lateral ankle sprains (LAS) and overuse injuries account for 73.6% and 31% of reported lower-limb injuries, respectively, during military fitness training programs.[1] Repetitive exposure to these injuries damages the lateral ligamentous support of the ankle joint and leads to chronic ankle instability in 70% of individuals.[2] The US military loses millions of dollars each year due to medical discharges from overuse injuries.[3] Residual symptoms after LAS can limit the activity of military personnel from 6 weeks to 18 months.[4]

Problem

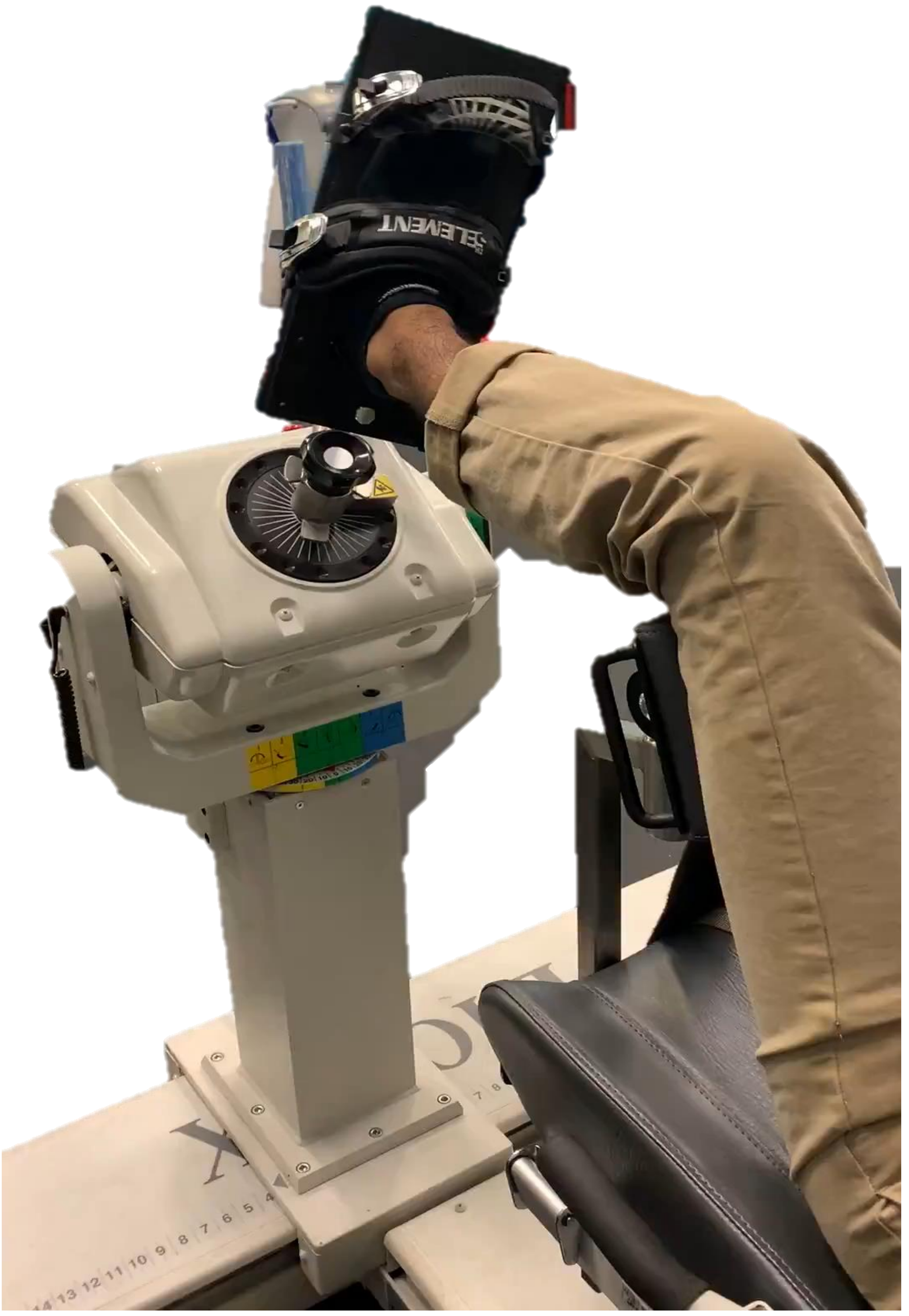
While military combat boots are tested in a variety of configurations to determine tolerance to heat and cold, sole flexion, toe compression, and slip resistance, the current footwear evaluation methodology lacks any lateral stability assessment.

Methods

- Fifty healthy volunteers (25m/25f) with no pre-existing ankle problems
- Range of motion was quantified in plantar flexion, dorsiflexion, inversion, and eversion
- Bilateral passive-stiffness measurements were taken in plantar flexion, dorsiflexion, inversion and eversion using a Biodex isokinetic dynamometer (Biodex Medical Systems, Inc.)
- Tests were repeated with the THOR and Hybrid III ATD legs

Objective

This study aims to examine ankle stiffness and range of motion in a healthy, young adult population and use these data to determine the biofidelity of current ATD designs during low-rate loading to the ankle joint.



References

1. Kucera KL et al. (2016). Med Sci Sports Exerc.
2. Gribble PA et al. (2019). J Athl Train.
3. Chalupa et al. (2016). AMEDD J.
4. Hertel J et al. (2002). J Athl Train.

Results

Table 1: Left ankle peak average stiffness response ± SD (Nm/°) at 60°/s and significance at α = 0.05.

	Plantar Flexion	p-value	Dorsiflexion	p-value	Inversion	p-value	Eversion	p-value
THOR	2.6	-	3.2	-	1.4	-	1.7	-
All Subj (n=50)	1.77 ± 0.2	*0.00	1.44 ± 0.3	*0.00	1.64 ± 0.2	*0.00	1.54 ± 0.2	*0.01
Male (n=25)	1.86 ± 0.2	*0.00	1.57 ± 0.3	*0.00	1.70 ± 0.1	*0.00	1.47 ± 0.1	*0.00
Female (n=25)	1.68 ± 0.1	*0.00	1.30 ± 0.2	*0.00	1.58 ± 0.1	*0.02	1.61 ± 0.2	0.34

	Plantar Flexion	p-value	Dorsiflexion	p-value	Inversion	p-value	Eversion	p-value
H3	1.9	-	2.8	-	1.8	-	1.9	-
All Subj (n=50)	1.77 ± 0.2	*0.03	1.44 ± 0.3	*0.00	1.64 ± 0.2	*0.00	1.54 ± 0.2	*0.00
Male (n=25)	1.86 ± 0.2	0.64	1.57 ± 0.3	*0.00	1.70 ± 0.1	*0.03	1.47 ± 0.1	*0.00
Female (n=25)	1.68 ± 0.1	*0.01	1.30 ± 0.2	*0.00	1.58 ± 0.1	*0.00	1.61 ± 0.2	*0.00

Conclusions

Current ATD leg designs do not appropriately model the human foot-ankle response under low-velocity lateral loads. A more biofidelic foot-ankle surrogate should be designed and validated for use in ankle stability-testing methodology for evaluating footwear.

Acknowledgements

This research was sponsored by the Army Research Laboratory. The views and conclusions contained in this document should not be interpreted as representing the official policies of the Army Research Laboratory or the US Government.