Effects of load carriage on natural ankle quasi-stiffness

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Introduction

Soldiers commonly carry heavy loads throughout the course of their military career. However the effects of this load on the muscles and general kinematics of the lower limb area is not fully understood.

In a specific study, the effects of weight as well as mass on specific muscles was determined. After examining the gastrocnemius and soleus, both plantar flexor muscles, it was concluded that there was a significant increase in muscle activity as a result of the addition load (Kram et al, 2008). The crucial role of plantar flexor muscles in reference to walking leads to the hypothesis that load would have a significant effect on alternative aspects of gait.

Plantar flexor muscles propel the body forward by eccentrically contracting in order to control forward shank rotation as well as store mechanical energy. Natural ankle quasi-stiffness (NAS) is a quantitative measure of the ankle's ability to control shank forward rotation. It can be described as the change the plantar flexor moment divided by the change in dorsiflexion angle during stance-phase of dorsiflexion. By understanding aspects of this characteristic, adjustments can be made to the bending stiffness of ankle foot prosthetics and orthotic devices. In this study the effects of three different load sizes, 10% body weight (BW), 20% BW, and no load, on ankle stiffness were examined in order to determine if a significant difference exists between the values with the hypothesis that NAS will increase with respect to load carriage.

Materials and Methods

Sixteen college-aged individuals consented to participate in this study. Prior to data collection, anthropometric measurements of all subjects were recorded. Reflective markers were attached to lower extremities and the trunk area, as pictured in Figure 1. Subjects underwent a gait analysis while walking at 0.8 statures/second (percent of walking speed normalized by the subject's height) under three load conditions: no external load, a weighted vest with 10% body weight (BW), and a weighted vest with 20% BW (Figure 2). For the gait analysis, 12 Qualysis® motion capture cameras were set up around three Bertec® force plates, as shown in Figure 3.

Figure 1 (left): Reflective markers were placed on specific anatomical locations on the lower limb and trunk as shown.

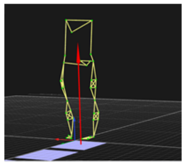
Figure 2 (right): Subjects wore the weighted vest for two of the load carriage conditions.

Materials and Methods (cont.)

Figure 3 (left): Subjects walked across the green strip. Towards the center of the green strip three force plates collect data on force applied by subjects during multiple gait cycles. Following each trial, it was determined whether the speed of the subject was within the correct range. Data was analyzed for this trial later during post processing.

Qualisys Track Manager® was utilized to identify the locations of specific markers placed on the subject (Figure 4). These files were then exported as C3D files and analyzed in Visual 3D©. Anthropometric data was added to a template code to model each subject's static position. The model template was then applied to the dynamic files. Ankle moment and ankle angle were then computed for each trial for each load condition. The average ankle stiffness for each load condition for each subject was then analyzed.

Figure 4 (right): During data processing, a model is produced in Qualysis®, as shown. This model is later exported to a separate program, Visual 3D©, and an ankle stiffness value is obtained.



Results

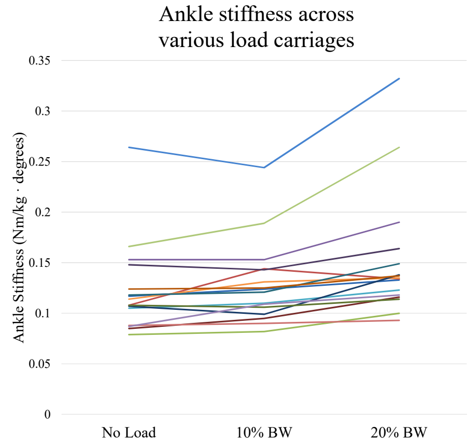
Ankle stiffness data was obtained for both the dominant and non-dominant legs, for each subject, as shown in Table 1. A dependent *t*-test was performed and it was determined that there was no statistical difference between the dominant and non-dominant legs. Therefore, the average stiffness for each individual at each load carriage consisted of the mean between the dominant and non-dominant legs, a graph of which is shown in Graph 1.

Ankle stiffness and components

	No Load	10% BW	20% BW
Ankle Stiffness (Nm/kg · degrees)	−0.12	−0.12	−0.15
Ankle Moment (Nm/kg)	−1.48	−1.63	−1.75
Ankle Angle (degrees)	13.5	13.9	13.2

Table 1 (left): This table shows the mean ankle stiffness for each load condition as well as the mean components of ankle stiffness – ankle moment and ankle angle. As viewed in the table, ankle moment is the changing variable while ankle angle remains relatively stable throughout the various loads.

Results (cont.)



Graph 1 (left): This line graph displays the mean ankle stiffness value for each load carriage for all subjects ($N = 16$). The absolute value of each ankle stiffness value was plotted. The general trend suggest an increase in ankle stiffness as load carriage increases.

Since no significant difference was found between the dominant and non-dominant legs, a one-way ANOVA with repeated measures was computed. With an alpha level of 0.05, there was a significant difference between no load and 20% BW ($p = 0.001$) and 10% BW and 20% BW ($p = 0.008$).

Conclusions

The purpose of this study was to determine if load carriage has an effect on ankle stiffness, in which the results portrayed a correlation between the two variables for the no load versus 20% BW comparison and the 10% versus 20% BW comparison. Since the *p*-value did not exceed 0.05, the data shows a rejection of the null hypothesis thus leading to the conclusion that as load size increases, ankle stiffness increases as well. In reference to the development of passive ankle foot orthotics, this information will allow for a more clear understanding of gait. By comprehending the characteristics of gait and the variables that alter gait patterns, researchers can adjust the bending stiffness of ankle foot orthotic devices in order to replicate the NAS of healthy individuals. In the future, it would be extremely beneficial to analyze similar data within a military population as well as an increased load size.

References

Kram, R., McGowan, C. P., & Neptune, R. R., (2008). Independent effects of weight and mass on plantar flexor activity during walking: implications for their contributions to body support and forward propulsion. *Journal of Applied Physiology, 105,* 486-494.