EFFECT OF DYNAMIC ANKLE JOINT STIFFNESS ON JOINT MECHANICS AND MUSCLE ACTIVATION PATTERNS DURING LOCOMOTION

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INTRODUCTION

Ankle-foot orthotics (AFOs) are external orthopaedic devices that provide support for foot-drop or ankle instability associated with many neuromuscular disorders. Currently, AFOs are articulated or rigid. Dynamic joint stiffness (JS) can be calculated as the slope of a joint angle vs. moment plot and is an important constraint on the motor control system as it affects the generation of voluntary movements and the displacement resulting from an external perturbation [1]. Understanding JS is essential to orthotic design and the quantitative evaluation of neuromuscular diseases [2]. JS has not been examined experimentally or dynamically with the use of AFOs in human locomotor activities. The effects of dynamically varied AFO stiffness on joint kinematics, kinetics, muscle activation patterns and resultant JS during walking and stepping down from a platform were the focus of this study.

METHODS

Bilateral AFOs were instrumented with electro-hydraulic disc brakes to allow for computer-adjustable AFO stiffness, which permitted varied external resistance of ankle motion. The study design was prospective, randomized, and was comprised of six healthy adult males. 3D kinematics were acquired using unilateral, lower-extremity active marker placement and a high-speed, motion analysis system (CODAmotion MPX30; Charnwood Dynamics Ltd., UK). Force plate (AMTI; 2000 Hz), electromyographic (EMG) (MA-310; Motion Lab Systems, Inc. Los Angeles, CA, USA; 2000 Hz), and video (200 Hz) data were collected during a minimum of 15 successful walking and 10 step down trials per subject for Shod (shoes only) and 3 AFO stiffness conditions: rigid (Rigid), articulated (Art), and intermediate (Inter). Time-frequency analysis, using wavelets, was used for EMG analysis to identify low (20-38 Hz) and high (128-218 Hz) frequency content of the EMG signals. Multivariate analysis of variance with a *post-hoc* test (α=0.05) revealed significant differences.

RESULTS AND DISCUSSION

During both gait and step downs there were no significant differences in mean resultant ankle or knee joint stiffness, independent of AFO use and AFO stiffness for both tasks. During the stance phase of gait, there was a significant decrease in ankle joint energy production at toe-off when AFO conditions were compared to Shod (Fig. 1). There was also a significant decrease in energy absorbed at the knee joint following heel-strike in the AFO conditions. During the step down task, there was a significant increase in energy absorbed across the ankle and knee joints in all AFO conditions compared to Shod (Fig. 1). The tibialis anterior (TA) muscle showed a significant increase in activation for all AFO conditions for walk and step down trials across all frequency bands (Fig. 2). There was significantly greater recruitment of the lateral gastrocnemius (LG) in all AFO conditions for step downs, but a decrease in activation for the AFO walking trials (Fig. 3). There were AFO condition and frequency dependent changes in EMG signals for both tasks.

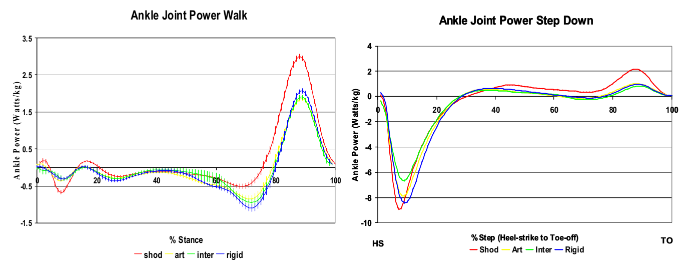

Fig. 1: Mean (±se) ankle joint power for walk (left) and step downs (right) for Shod (red) Art (yellow), Inter (green) and Rigid (blue). N=6

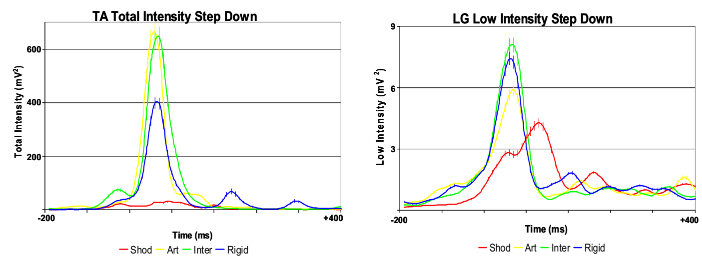

Fig. 2: Mean (±se) TA total intensity (left) and LG low intensity (right) for 200ms pre- and 400ms post-step down for Shod (red) Art (yellow), Inter (green) and Rigid (blue) conditions. N=5

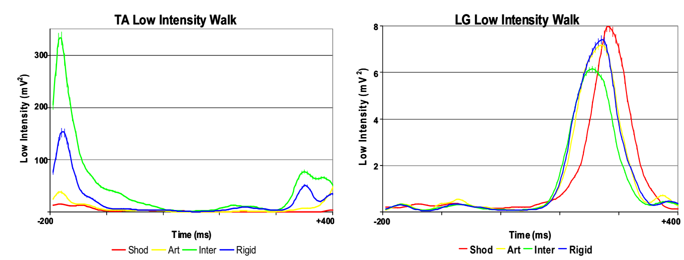

Fig. 3: Mean (±se) TA low intensity (left) and LG low intensity (right) for walking trials for Shod (red) Art (yellow), Inter (green) and Rigid (blue) conditions. N=5

CONCLUSIONS

Despite changes in AFO stiffness, resultant ankle and knee joint stiffnesses remained unchanged for both walking and step down trials; however, there were changes in muscle activation patterns and mechanical joint energetics. That suggested that a neuromotor and joint dynamics response helped maintain a task-specific resultant joint stiffness. These findings are consistent with JS being a function of task [3] and therefore, task-specific AFO stiffness may be more desirable in clinical populations. Results from this study provide data to help in our understanding of how AFO prescription may affect internal joint mechanics and muscle activation patterns.

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