

DYNAMIC ANKLE STABILITY AND ANKLE ORIENTATION

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INTRODUCTION

Dynamic ankle stability can be defined as the ability of the ankle joint to maintain equilibrium in response to an external perturbation. Maintaining ankle stability during gait and other activities is necessary in order to prevent any injuries. Dynamic ankle stability is influenced by passive mechanisms such as ligamentous stiffness, active mechanisms such as muscle stiffness, and neuromotor mechanisms such as reflex and voluntary control.

Most ankle sprains occur along lateral ligament complex via an inversion mechanism (Baumhauer, 1995). Previous research examined dynamic inversion stabilization and ankle stiffness via a sudden perturbation experiment (Zinder, 2002). However, no study has yet examined this dynamic stabilization as a function of ankle orientation. In this study the variation of dynamic ankle stiffness and dynamic inversion stabilization was examined as a function of ankle inversion and eversion in order to better understand dynamic inversion stabilization.

METHODS

Five healthy subjects (2 female and 3 male) between the ages of 21 and 31 with no history of ankle injury were recruited for the study, which was approved by the Humans Subject Committee, University of Kansas. In this experiment subject were asked to stand with one foot on a cradle platform and one foot on a force plate while a sudden inversion perturbation was applied to the platform. Dynamic motion of the cradle and foot as well as muscle activity were then assessed in order to examine the dynamic stabilization of the ankle.

A variable capacitance accelerometer (Endevco, San Juan Capistrano, CA) was fastened to the base of the cradle platform to record the oscillation of the platform during perturbation. A 3-D electromagnetic motion analysis system, Motionstar, (Ascension Tech., VT) was used to assess dynamic ankle motion. Five electromagnetic markers were placed on the foot region over the navicular, cuboid, first and fifth proximal phalanges and tibia using double sided tape. Four surface electromyography electrodes (Delsys, Boston, MA) were attached to the skin over tibialis anterior, medial gastrocnemius, lateral gastrocnemius and the soleus.

Subjects were asked to stand on the cradle platform with one foot on the platform in such a way that the talocrural joint of the ankle was aligned with the axis of rotation of the device and the other foot was on the force plate. They were asked to concentrate on a visual display unit and distribute their weight such that 30%, 50%, 70% of their body weight was on the cradle platform at different trials. Two wedges of 5 and 10-degrees were placed beneath the foot and were rotated in the different orientations (inversion and eversion) in a random order. Three sudden perturbation trials were performed for each orientation. A no wedge, neutral orientation condition was also performed where the subject stood on a flat support. At each of these conditions a tennis ball filled with lead shots was dropped from a height of 1.5 meter on to the platform resulting in an inversion perturbation.

Oscillations of the platform were analyzed using fast Fourier transformation and a logarithmic decrement method to obtained frequency and decay of successive oscillations. Ankle stiffness and damping were then obtained using the equation:

$$(I_{\text{foot}}+I_{\text{cradle}})s^2+Bs + (K_{\text{ankle}}+(mgl)_{\text{cradle}}+(mgl)_{\text{foot}}) = M_p$$

where K_{ankle} is the rotation stiffness of the ankle, B is the damping constant, and M_p is the perturbation moment. Inertia of the foot (I_{foot}) was determined from literature data (Winter, 1990). Inertia and pendular dynamics of the cradle (I_{cradle} and $(mgl)_{\text{cradle}}$) were determined through a separate assessment of the cradle without a subject.

RESULTS

Average dynamic ankle stiffness at 50% weight bearing and neutral orientation was found to be 58.9 Nm/rad with a range of 33.2-110.7 Nm/rad. This is slightly larger but within the range of previous studies of dynamic ankle stiffness (Zinder, 2002). The ankle stiffness was found to be significantly increased with increasing weight on the perturbed foot (Figure 1). Ankle stiffness was found to be lowest in a neutral foot orientation and increased with inversion and with eversion (Figure 1).

DISCUSSION

The results from the study show that the stiffness changes with weightbearing such that the stiffness is greater with increased loading of the joint. In addition, dynamic ankle stiffness increased as the foot was rotated in either inversion or eversion away from the neutral orientation. This dynamic ankle stiffness is a function of passive ligamentous and other soft tissue stiffness, active muscle stiffness, and neuromotor control. With increased weightbearing, increased muscle activation could lead to increased muscle stiffness around the joint and increased dynamic ankle stiffness. In addition the ankle joint would be compressed, potentially increasing the stiffness contribution of the articular cartilage of the ankle joint.

In the neutral orientation, passive ligamentous contributions to dynamic ankle stiffness are likely small. This is evidenced by the free and easy rotation of the inactive ankle. Therefore, much of the dynamic ankle stability must come from the muscle stiffness and neuromotor control. As the ankle is rotated into either inversion or eversion, passive stiffness contributions would increase limiting ankle rotation outside the normal range of rotation. Neuromotor control would also increase as stretch of ligamentous tissues contributes to the neuromotor response dynamics (Solomonow, 2002).

Future research will examine the changes in dynamic lateral ankle stabilization as a function of dorsi and plantar flexion. In addition, the changes in ankle stiffness as a function of inversion and eversion will be examined in both control subjects and subjects with a history of chronic ankle instability in order to better understand the effect of chronic ankle instability changes on dynamics ankle stabilization.

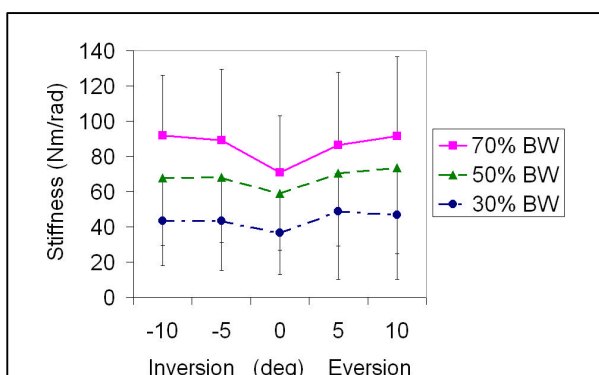


Figure 1 Dynamic Ankle Stiffness increased with increased weightbearing on the ankle (BW) and with both increased inversion and eversion.

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