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Assessment of passive ankle stiffness: A new device allowing for a variable center of rotation

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Introduction: Joint stiffness is a mechanical property, which is represented by the slope of the torque-angle curve and describes the resistance of a joint during movement. The assessment of the passive ankle stiffness adds a useful parameter to the ankle joint properties used for modeling and motion analysis. Despite a number of devices have been developed to measure the passive ankle joint stiffness [1-3], none could be used for both degrees of freedom: dorsiflexion (DF) - plantarflexion (PF) and eversion (EV) - inversion (IN). Further all devices implemented a fixed rotation axis, which may affect the measurement accuracy due to a moving center of rotation during ankle motion [4].

The purpose of this study was to present a manual device to measure the passive ankle joint stiffness for DF-PF and EV-IN motions.

Subject and Method: Figure 1 shows the general setup. By rotation of the subject and the footplate 90° the two motion directions were measured. One healthy male subject (age: 29, height: 1.7m, weight: 72kg) with no prior ankle injuries was included in the study. The leg was fixed to the stand by straps, and the foot fixed by a shoe attached to the footplate. The experimental procedure included three sets of 10 cyclic manual movements of the handle to the end points of the ankle range of motion at three different velocities. Torque and force (sensor: AMTI FS6), and inclination (sensor: VTI SCA61T) data were sampled at 1kHz and analyzed offline. To estimate the effect of the angular velocity on the ankle stiffness, a cubic fit was computed to assess the velocity dependence of passive joint stiffness.

Results: The applied mean velocities were computed and labeled as slow (35°/s), normal (57°/s) and fast (226°/s). Figure 2 shows the torque-angle curves for the DF-PF movement. The ankle range of motion was -25.1° to 30.7° for DF-PF and -30.6 to 34.1 for EV-IN movements. The cubic, quadratic and linear coefficients of the cubic fit showed a negative trend by increased angular velocity, indicating a lower stiffness during the fast movement compared to the slow movement.

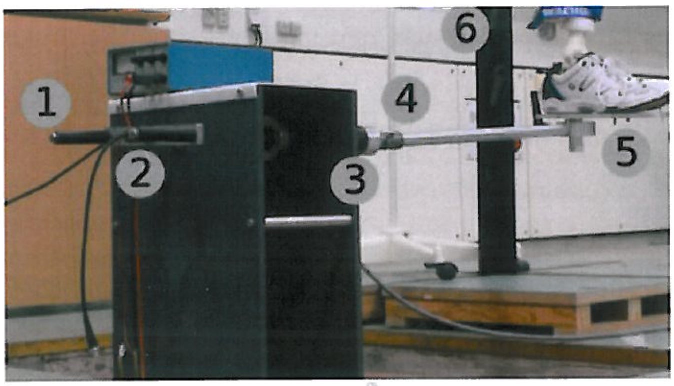

Figure 1: Experimental setup: 1: Handle, 2: Inclination sensor, 3: Force sensor, 4: Gimbal Joint, 5: Foot plate, 6: Stand.

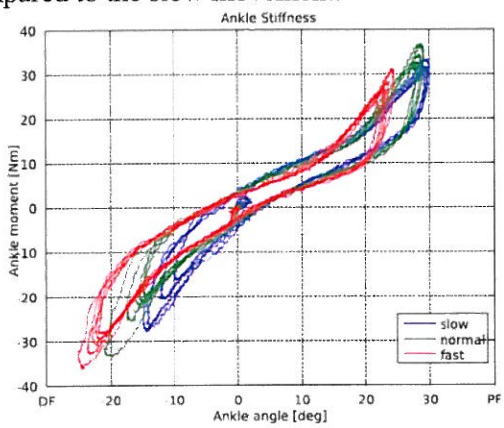

Figure 2: Stiffness of the ankle during dorsi-plantar flexion.

Conclusion: The results showed that the device produced consistent measurements, which need to be validated in the future.

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