Measurement of Resistive Plantar Flexion Torque of the Ankle during Passive Stretch in Healthy Subjects and Patients with Poststroke Hemiplegia

Shiho Mizuno, MD, PhD,* Shigeru Sonoda, MD, PhD,* Kotaro Takeda, RE PhD,† and Shinichiro Maeshima, MD, PhD*

Background: Quantification of increased muscle tone for patients with spasticity has been performed to date using various devices to replace the manual scales, such as the modified Ashworth scale or the Tardieu scale. We developed a device that could measure resistive plantar flexion (PF) torque of the ankle during passive dorsiflexion (DF) as an indicator of muscle tone of ankle plantar flexors. *Methods:* The primary objective was to explore the test–retest intrarater reliability of a custom-built device. Participants were 11 healthy subjects (7 men, 4 women; mean age 47.0 years) and 22 patients with poststroke hemiplegia (11 hemorrhagic, 11 ischemic; 14 men, 8 women; mean age 57.2 years). The device was affixed to the ankle. Subjects were seated with knees either flexed or extended. The ankle was passively dorsiflexed from 20° of PF to more than 10° of DF at 5°/second (slow stretch) or 90°/second (fast stretch). Angle and torque were measured twice during the stretches. The intraclass correlation coefficients (ICCs) of torque at 10° of DF (T10) in the 4 conditions—slow and fast stretches with knee flexed or extended—were calculated. *Results:* The T10 ICCs of the 4 conditions were .95-.99 in both groups. The healthy subjects showed significantly higher T10 of knee extension than of knee flexion during slow and fast stretches. The patients showed increased velocity-dependent torque during fast stretches. *Conclusions:* Excellent reliability was observed. The device is suitable for measuring resistive PF torque during passive stretch in a flexed knee condition. **Key Words:** Quantitative evaluation—increased muscle tone—stroke—spasticity.

Introduction

Persons with poststroke hemiplegia often exhibit increased muscle tone. Accentuated ankle plantar flexor muscle tone leads to a spastic equinus foot, one of the major causes of various gait abnormalities such as delayed heel rise because of reduced ankle dorsiflexion (DF) at a stance, toe-dragging on the ground because of reduced toe clearance, or circumduction during swing.[1] Therefore, the evaluation of the muscle tone of the ankle planar flexor is indispensable. The resistance during passive stretch to DF of the ankle joint has been presumed to be due to the muscle tone of the ankle plantar flexor muscles in the clinical setting because it is impossible to evaluate individual muscle tone separately using biomechanical measurements or manual tests. In the current study, we

From the *School of Medicine, Department of Rehabilitation Medicine II, Fujita Health University, Mie, Japan; and †Fujita Memorial Nanakuri Institute, Fujita Health University, Mie, Japan.

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Address correspondence to Shiho Mizuno, MD, PhD, School of Medicine, Department of Rehabilitation Medicine II, Fujita Health University, 424-1 Ohtori-cho, Tsu City, Mie 514-1295, Japan. E-mail: shiho.mizuno@gmail.com.

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used resistive plantar flexion (PF) torque during passive DF of the ankle joint as a muscle tone indicator of ankle plantar flexors.

To date, manual tests remain the primary method used to measure muscle tone. The modified Ashworth scale[2] has been widely used due to its ease of use. The scale is used to grade the resistance of a relaxed limb to rapid passive stretch in 6 stages. The Tardieu scale[3] is another clinical muscle tone measurement tool that compares how spastic muscles "catch" at low, medium, and high velocities. However, the poor inter- and intrarater reliabilities of both scales are a problem.[4-8] Therefore, a quantitative assessment of muscle tone is needed and has been attempted using biomechanical measures.

In previous studies, isokinetic dynamometers or custom-built devices were used concurrently with electromyography to quantify muscle tone.[9-22] The instrumentation systems were large and rather immobile, and the test duration including patient positioning and setup required 60-90 minutes.[9] The measurement itself involves DF of the ankle, which takes just a few seconds, but the overall test duration is long enough to preclude their routine use as a clinical assessment tool. The systems reported previously could not always provide immediate results, which also prevent their clinical use, and to date they have been used only in research. For the adaptation to routine clinical use of the instrumentation systems to evaluate muscle tone, a shorter overall test duration, easy setup and installation, and simple interpretation of the results are required. In previous studies, subjects were asked to transfer to a special chair or bed for the experimental setup. Most persons with poststroke hemiplegia in the present study used a wheelchair and needed assistance to move to a chair or bed. Therefore, we developed a device that could quantitatively measure resistive PF torque during passive stretch as an indicator of muscle tone of ankle plantar flexors and devised a way to measure smoothly while the subjects remained seated in their wheelchairs.

The objectives of the current study were

1. to explore test–retest intrarater reliability for the newly developed device to quantify resistive PF torque during passive stretches among the healthy subjects and patients with hemiplegia and
2. to compare resistive PF torque among the healthy subjects and patients with hemiplegia as an indicator of PF muscle tone.

Materials and Methods

Participants

The participants included 11 healthy subjects (7 men, 4 women; median age 47.0 years) and 22 poststroke patients (14 men, 8 women; median age 59.5 years). Patients with hemiplegia who were admitted to inpatient rehabilitation wards in our hospital for poststroke rehabilitation between April and July 2013, were younger than 71 years old, and did not have a history of lower leg and foot injuries or any other impairment that might affect ankle torque were included in the study. The demographic characteristics of the patients with hemiplegia are shown in Table 1.

Device: Angle and Torque Measurement System (Atom)

The design, characterization, data collection, and system procedure were described previously.[23] Here we briefly summarize its design. The device is made of a double-upright ankle foot orthosis, a motor to dorsiflex the ankle joint, a torque meter to measure PF torque, and a potentiometer to measure the ankle joint angle. The motor is controlled to rotate the ankle joint with a preset constant velocity using a controller.

The outputs of the potentiometer and the strain amplifier are transferred to a computer through a data logger at a sampling rate of 1 kHz.

Ankle bars are located at the medial and lateral portions of the ankle joint on the orthosis. The ankle bars and the ankle box can support the lower leg and foot, which serve to minimize each subject's leg and foot weight.

Before the Atom tests, a practitioner (the corresponding author, S.M.) performed the following physical assessments: motor paresis severity of the lower extremities by Brunnstrom stage,[24] muscle force of the ankle dorsal flexors by manual muscle testing, frequency of ankle clonus, and muscle tones of the ankle plantar flexors according to the modified Ashworth scale. The device was applied to the right ankle of the healthy subjects and to the affected ankle of the patients with hemiplegia. The subjects were seated in a chair with the knee flexed at 60°, the lower leg parallel to the floor (flexed knee position) or with the knee extended, and the leg parallel to the floor (extended knee position). A photo of the flexed knee position with Atom is shown in Figure 1. The ankle was passively dorsiflexed from 20° PF to more than 10° DF at an angular velocity of 5°/second (slow stretch) or 90°/second (fast stretch). A ramp-and-hold method was applied for passive DF. The hold time was 3 seconds. Movement velocity of the fast stretch was chosen based on a previous observation that the stretch reflex appears in the electromyography (EMG) at approximately 75°/second.[13]

After a 3-minute rest, a coauthor, K.T., who was blinded to the physical assessments, performed the test–retest examinations in the following 4 conditions; the flexed knee-slow stretch of the ankle joint (flx-Slow), flexed knee–fast stretch of the ankle joint (flx-Fast), extended knee–slow stretch of the ankle joint (ext-Slow), and extended knee–fast stretch of the ankle joint (ext-Fast) conditions. Each test interval was 3 minutes. The subjects were asked to remain relaxed throughout the