

# Reliability of ankle dorsiflexion passive range of motion measurements obtained using a hand-held goniometer and Biodex dynamometer in stroke patients

IN-GUI JUNG, PT, BHSc<sup>1</sup>, IL-YOUNG YU, PT, BHSc<sup>1</sup>, SOO-YONG KIM, PT, BHSc<sup>1</sup>,  
DONG-KYU LEE, PT, PhD<sup>2</sup>, JAE-SEOP OH, PT, PhD<sup>3</sup>\*

<sup>1</sup>) Department of Physical Therapy, Graduate School, Inje University, Republic of Korea

<sup>2</sup>) Department of Rehabilitation Science, Graduate School, Inje University, Republic of Korea

<sup>3</sup>) Department of Physical Therapy, College of Biomedical Science and Engineering, Inje University:  
607 Obang-dong, Gimhae-si, Gyeongsangnam-do 621-749, Republic of Korea

**Abstract.** [Purpose] This study investigated the reliability of ankle dorsiflexion passive range of motion (DF-PROM) measurements obtained using a goniometer and Biodex dynamometer in stroke patients. [Subjects] Fifteen stroke patients participated in this study. [Methods] Ankle DF-PROM was assessed using a goniometer and Biodex dynamometer. Ankle DF-PROM was measured during two sessions with 7 days between tests. Intraclass correlation coefficient, standard error of measurement, and minimal detectable change values were used to assess the reliability of measurements obtained using both instruments. [Results] The intra-rater reliability for ankle DF-PROM using the goniometer was moderate and good for the two raters, while using the Biodex dynamometer, it was good for both raters. Inter-rater reliability using the goniometer was moderate; using the Biodex, it was good. [Conclusion] Both intra- and inter-reliability measurements of ankle DF-PROM were higher using a Biodex dynamometer than with a goniometer.

**Key words:** Biodex reliability, Ankle dorsiflexion passive range of motion, Stroke

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## INTRODUCTION

Stroke patients typically walk on their forefoot because of excessive ankle plantar flexion, a result of extensor spasticity, plantar flexion contracture, or dorsiflexor weakness<sup>1</sup>. Degeneration in ankle joint motion, caused by tightness in the Achilles tendon and subsequently a reduced range of motion, can result in clumsy gait patterns and increased energy cost<sup>1, 2</sup>. Ankle dorsiflexion passive range of motion (DF-PROM) during functional activities is frequently assessed in physical therapy<sup>3</sup>.

Several studies have used a goniometer to measure maximal ankle DF-PROM during the transition from passive movement to dorsiflexion, until “firm” resistance is achieved, even in stroke patients<sup>4-7</sup>. Exact quantification of ankle DF-PROM using this method can be problematic. During spasticity, a condition typical in stroke patients, more rapid passive stretching of the muscle results in commen-

surately increased resistance<sup>8</sup>. Therefore, stroke patients, who are particularly sensitive to movement velocity, may require more precise assessment by maintaining constant velocity while adjusting resistance throughout a joint’s range of motion using an isokinetic dynamometer<sup>9</sup>. The Biodex System-3 isokinetic dynamometer (Biodex Medical Systems, Shirley, New York, USA), which can be used in both clinical and research settings<sup>9</sup>, reliably measures both torque and angular velocity<sup>9-11</sup>. However, few studies have assessed the reliability of range-of-motion measurements obtained using an isokinetic system or goniometer.

Although stroke patients are sensitive to passive movement velocity (due to spasticity)<sup>8</sup>, passive range of motion can be assessed without considering movement velocity by using an isokinetic system. This study assessed the reliability of DF-PROM measurements obtained using a goniometer and Biodex dynamometer in stroke patients.

## SUBJECTS AND METHODS

In total, 15 stroke patients (3 female and 12 male; mean age = 49.4 ± 11.9 years; mean height = 166.4 ± 7.0 cm; mean weight = 68.4 ± 9.8 kg; time since onset = 12.1 ± 14.5 months; affected side [left/right] = 12/3) participated. The inclusion criteria were a minimum of 0° passive ankle dorsiflexion and an absence of significant lower extremity

\*Corresponding author. Jae-Seop Oh (E-mail: ysrehab@inje.ac.kr)

pain and/or sensory deficits. In order to participate, all subjects had to exhibit sufficient communicative and cognitive capabilities (Mental Status Examination score > 24). The muscle tone of plantar flexors was measured by a physician using the Modified Ashworth Scale (MAS). Subjects were excluded if they exhibited lower extremity fracture or ankle contracture (MAS  $\geq$  3). All participants signed a consent form approved by the Institutional Research Review Committee of Inje University prior to their participation.

All tests were performed using a Biodex isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY, USA). Each subject was seated in the adjustable chair of the dynamometer, with the paretic leg to be measured elevated by a support arm placed under the knee. A hand-held goniometer was used by a physical therapist to set hip and knee joint angle and measure ankle DF-PROM. The angle of the hip and knee joints was set at 80° (0° neutral position) and 30° flexion (0° straight leg), respectively<sup>12</sup>.

During dynamometer testing, the subject's ankle was placed on the footplate and the foot was fixed using Velcro and elastic straps; the top of the foot was tied tightly. All subjects were tested in bare feet. Two diagonal standard Velcro straps were used to stabilize the trunk, and an additional strap was used to secure the hip. The contralateral thigh was also secured using a single Velcro strap. Ankle DF-PROM was measured while the subject was seated within the Biodex dynamometer. Ankle dorsiflexion of 0° was indicated by the tibia being perpendicular to the sole of the foot<sup>12</sup>.

Throughout the study, all tests were performed by two raters. Only the paretic ankle was tested during two sessions (the first using the goniometer and the second the dynamometer). During each session, tests were performed on three occasions; prior to each session, pre-testing was conducted to ensure participants were sufficiently familiar with the test procedure. Goniometer or isokinetic measurement was also performed three times by each rater during pre-testing, with the second session initiated after a 2-min rest period. Therefore, each subject underwent a total of 12 trials, all scheduled at approximately the same time of day, with 7 days between tests.

Intraclass correlation coefficients (ICC) were calculated to determine the intra-rater (ICC<sub>3,3</sub>) and inter-rater (ICC<sub>2,3</sub>) reliability of ankle DF-PROM measurements. An ICC > 0.75 was considered good, 0.5–0.75 was moderate, and < 0.5 was poor<sup>13</sup>. Standard error of measurement (SEM) and minimal detectable change (MDC) values were calculated to assess consistency using the Microsoft Office Excel software package (Microsoft Corp., Redmond, WA, USA). SEM was calculated by the following formula: standard deviation (SD)  $\times \sqrt{1 - \text{ICC}}$ . MDC<sub>95</sub> was calculated by  $1.96 \times \text{SEM} \times \sqrt{2}$ <sup>14</sup>. Statistical analyses were performed using the SPSS for Windows software package (ver. 21.0; IBM Corp., Armonk, NY, USA), and a value of  $p < 0.05$  indicated statistical significance.

## RESULTS

Data were collected from a total of 15 subjects. Mean  $\pm$  SD values for ankle DF-PROM measured using a goniometer and the Biodex dynamometer were  $14.1 \pm 3.6^\circ$  and

$17.3 \pm 4.9^\circ$ , respectively. The intra-rater reliability for ankle DF-PROM using the goniometer was 0.719 and 0.892 for the two raters ( $p < 0.05$ ), compared with 0.930 and 0.968 using the dynamometer ( $p < 0.05$ ). Inter-rater reliability using the goniometer ranged between 0.725 (first test) and 0.741 (second test,  $p < 0.05$ ), and between 0.938 (first test) and 0.947 (second test) when using the dynamometer ( $p < 0.05$ ). The SEM and MDC<sub>95</sub> values for each ankle DF-PROM measurement ranged between 0.8° and 2.0°, and 2.2° and 5.6°, respectively.

## DISCUSSION

We determined the inter- and intra-rater reliability of ankle DF-PROM measurements obtained using a goniometer and Biodex dynamometer in stroke patients. Eng et al. reported high reliability for lower-extremity strength measurements in chronic stroke patients<sup>15</sup>. Konor et al. assessed the intra-rater reliability of three measures of ankle DF-PROM, obtained using a standard goniometer, digital inclinometer, and tape measure, in conjunction with the distance-to-wall technique during weight-bearing lunges, in healthy subjects (ICC<sub>2,3</sub> = 0.85, 0.96, and 0.98, for the goniometer, inclinometer, and tape measure, respectively)<sup>16</sup>. The Biodex system is typically used to measure torque and angular velocity<sup>9–11</sup>, but it can also assess range of motion. To the best of our knowledge, the present study is the first to investigate the reliability of goniometer and Biodex dynamometer measurements of DF-PROM in stroke patients.

Goniometer measurement of ankle DF-PROM was associated with moderate and good intra-rater reliability, and with moderate inter-rater reliability. All inter- and intra-rater reliability values of measurements obtained using the Biodex dynamometer were good, ranging between 0.930 and 0.968. Both techniques were characterized by low measurement error (SEM =  $1.3^\circ$ – $2.0^\circ$  with the goniometer vs.  $0.8^\circ$ – $1.4^\circ$  with the Biodex dynamometer), suggesting that novice users can obtain reliable measures of ankle DF-PROM using either method. The MDC for the goniometer was  $3.6^\circ$ – $5.6^\circ$  compared with  $2.2^\circ$ – $3.3^\circ$  for the Biodex dynamometer; therefore, use of the Biodex appears preferable, particularly when measuring changes in range of motion before and after intervention.

Hong et al. reported similar intra-rater (tester 1 = 0.86, tester 2 = 0.77) and inter-rater (0.63) reliability values during measurement of ankle DF-PROM using a goniometer in healthy subjects<sup>17</sup>. Several previous studies have measured PROM using a goniometer to assess the effect of stretching in stroke patients<sup>4, 7</sup>. In the present study, ankle DF-PROM measurements obtained using a goniometer demonstrated moderate inter- and intra-rater reliability. Goniometer DF-PROM measurements were less reliable and tended to be associated with a lower degree of ankle DF-PROM compared with the Biodex dynamometer measurements ( $14.1^\circ$  vs.  $17.3^\circ$ , respectively), possibly because the goniometer used involved various speeds.

Our data indicate that clinical ankle DF-PROM measurement in stroke patients who are more sensitive to passive movement velocity due to spasticity, is more reliable when using a Biodex dynamometer than when using a goniometer.

eter<sup>8)</sup>. Because the Biodex dynamometer is an isokinetic device<sup>9)</sup>, testers may first have to practice using a goniometer to increase intra-rater reliability. In addition, although ankle DF-PROM measurements obtained using the Biodex dynamometer exhibited good reliability, the device is more expensive than a goniometer.

Generalization of our data is limited because subjects were not classified into acute, sub-acute, and chronic groups. Also, the Biodex dynamometer is very expensive to use in clinical settings. Therefore, additional research is required to evaluate measurements according to stroke severity and range of motion of another joint.

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