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# A novel clinical evaluation method using maximum angular velocity during knee extension to assess lower extremity muscle function of older adults

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ABSTRACT

The purpose of this study is to examine the utilities of maximum angular velocity (AV) assessment during knee extension (KE) using a gyroscope for clinical evaluation of exercise program for older adults. Two hundred and 4 community-dwelling older adults underwent a 3-month exercise intervention program. Outcome measures included AV during KE and other physical functions (isometric strength (IS), walking abilities, and balance functions). A correlation coefficient was used to evaluate the relationships between AV and other physical functions at baseline. The differences of physical functions before and after intervention were evaluated and the effect size of each measurement was calculated after the program. The AV measurement was significantly correlated with IS during KE ($r = 0.303$, $P < 0.01$) and other physical functions. Most correlation coefficients of angular velocity were greater than that of IS. All of physical assessments were significantly improved. Also, effect size of AV was greater than that of IS ($d = 0.45$ vs. 0.42). AV of the lower extremities is useful to evaluate the effects of exercise intervention in the elderly.

## 1. Introduction

Muscle function of lower extremities decreases with age and impacts walking speed and activities of daily living (Doherty, 2003; Hasegawa et al., 2008; Metter, Conwit, Tobin, & Fozard, 1997; Skelton, Greig, Davies, & Young, 1994). Therefore, a reliable method is needed to evaluate the muscle function of lower extremities of older adults at risk of functional decline. Generally, most previous research has focused on the maximum isometric strength (IS) during knee extension (KE), which is principally a measure of the strength of quadriceps femoris, because this method is relatively safe for older adults and adverse events are rare, especially when the examiner is well trained and adheres to documented methods (Kojima, Kim, & Saito, 2014).

On the other hand, measurement of IS among a large group of community-dwelling older adults presents some risks because many of them may be pre-frail or frail. The additional strain induced by measurement to the joint tissues (i.e., tendon, ligament, etc.) increases the risk of injury especially to frail elderly with limited exercise experience. Also, some elderly tend to stop breathing during muscle contraction even when breathing methods are practiced before measurement. In such cases, the risk of cardiovascular events also increases via the Valsalva maneuver (Soucek, Frana, & Kara, 2009).

Several important and interesting indications of muscle strength have been recently reported. Muscular power generated by vigorous joint motion in disabled older adults may be more directly related to impaired physical performance than IS, which is generated by fixed joints (Cuoco et al., 2004; Skelton et al., 1994; Suzuki, Bean, & Fielding, 2001; Sayers, Guralnik, Thombs, & Fielding, 2005). In addition, there is a greater occurrence of age-related decreases in maximal power production than of those in maximal muscle strength[3]. There is a positive association between muscle power and functional mobility tasks, and peak muscle power is a strong physiological predictor of functional limitations and disability in older adults (Bean, Kiely, & Herman, 2002; Foldvari, Clark, & Laviolette, 2000; Hasegawa et al., 2008; Sayers et al., 2005). In accordance with these insights, evaluation of the muscle power of lower extremities or other measurement values to safely extrapolate muscle power may be more beneficial than measuring IS. If we wanted to assess the muscle power, isokinetic devices were needed to monitor joint angular velocity during assessment of muscle power. Because of the inconvenience and expensiveness of those devices, so muscle power is not routinely assessed in clinical and community-based settings.

To overcome this problem, we employed a gyroscope to measure angular velocity (AV). Originally developed to control arm movement

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of robots, this device is both more compact and less expensive than isokinetic equipment. We recently demonstrated that its use in measuring maximum angular velocity during joint motion was both reliable and feasible, and that AV had a greater correlation with muscle power and some physical functions in Japanese, community-dwelling, older adults than did muscle strength (Arai et al., 2008, 2012). These results suggest that AV measured using a gyroscope might effectively assess muscle and physical function in community-dwelling older adults. If AV during KE is sensitive to the effects of exercise program for elderly people, measuring AV could be beneficial than measuring IS to assess the lower extremity muscle function which related the limitation of mobility in community-dwelling elderly people.

Therefore, the purposes of the current study were to determine usefulness of the AV during KE and related measurements of effects of the training for older people in a community setting and to compare sensitivity between AV and other clinical measurements.

## 2. Methods

### 2.1. Participants

We included 204 community-dwelling older adults (mean age ± SD, 78.6 ± 5.6 years) residing in the Tokyo metropolitan area; they were recruited through advertisements published in various community publications and through the encouragement of local public health nurses.

The inclusion criteria of the participation of exercise program executed by the local government were community-dwelling adults aged ≥65 years. The exclusion criteria for participation in exercise intervention defined by the Ministry of Health, Labour and Welfare of Japan were as follows: (i) a cerebrovascular or cardiovascular event within the past 6 months, (ii) acute liver problems or active chronic hepatitis, (iii) diabetes mellitus with a history of hypoglycemia or fasting plasma glucose concentrations of ≥200 mg/dl or complications, such as retinopathy or nephropathy, (iv) systolic blood pressure of > 180 mmHg or diastolic blood pressure of > 110 mmHg at rest, and (v) diagnosis of heart disease, acute orthopedic problem, or dementia made by a medical doctor and recommendation by the author that the subject be excluded. Because the inclusion and exclusion criteria were announced in the community publications and were made known to all public health nurses, 204 participants met the eligibility criteria. Nevertheless, a medical doctor confirmed that their physical activities were not restricted.

Although we did not quantitatively assess cognitive function, a medical doctor or public health nurse examined participants' current medical histories and, using a simple interview, confirmed that none were diagnosed with dementia or depression. Written informed consent was obtained from each participant. The study protocol was approved by the ethics committee of our institution and each local governmental entity.

### 2.2. Measurements

Evaluations were performed at the beginning and end of the intervention period. Measurements of physical function were performed by random order. The main measure of this study was the maximal joint angular velocity (AV) during KE. The gyroscope[a] (MicroStone Inc, Nagano, Japan.) used in this study is relatively compact (Fig. 1) and inexpensive, is not burdensome to patients, and does not inhibit human motion. We evaluated the angular velocity during KE using methods defined in previous study (Arai et al., 2012). To measure the angular velocity of the tibia against the thigh, a gyroscope was fixed on the distal position of the dominant limb so that the axis of the sensor was on the sagittal plane. The subjects were asked to sit on a chair with their knees and hips at 90° flexion and trunks upright. We adjusted the chair's height so that the subject's feet did not touch the floor. The subjects were allowed to grasp the chair to maintain trunk position, while the thigh was gently fixed with a strap to restrict vicarious movement. Each subject was asked to distally extend the knee of the dominant leg, which was attached to a 2 kg ankle weight, as quickly as possible (Fig. 2). A 2 kg ankle weight was chosen because it reportedly best facilitates the activities of the hamstrings that restrict the anteroposterior displacement of the tibia during movement (data published in a Japanese journal). Before the actual assessment, subjects practiced this task several times with sub-maximal effort, and the examiner confirmed that none had knee-related complaints. The task was performed three consecutive times, and the maximal angular velocity was recorded. Data from the gyroscope were captured at 200 Hz and transferred to a personal computer through an analog–digital convertor.

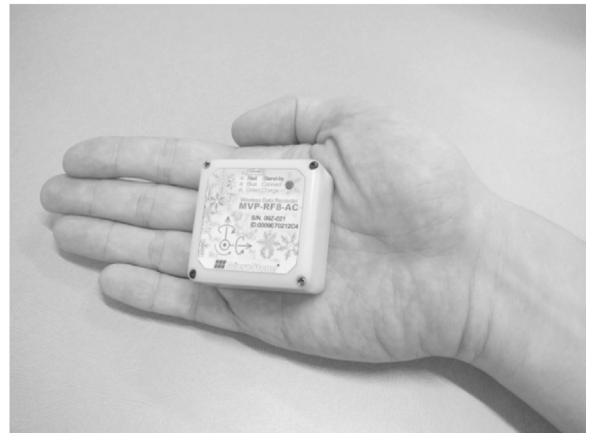

**Fig. 1.** Gyroscope.

Isometric KE strength of the dominant leg was measured twice with the subjects in the same position as described above, using a handheld dynamometer[b] (OG Giken Co., Ltd., Okayama, Japan), and the maximum value was recorded. Handgrip strength (HS) was measured using a hand-dynamometer[c] (Takei Scientific Instruments Co., Ltd., Niigata, Japan). HS and IS during KE were measured to represent upper and lower dominant limb strength, respectively.

The subjects performed a sequence of physical functional tests. The ability to stand on one leg for up to 60 s with the eyes open was used as an indicator of static balance; it was performed twice, and the maximum value was recorded. The functional reach test (FRT) (Duncan, Weiner, Chandler, & Studenski, 1990) was performed to measure dynamic balance. FRT was performed twice, and the maximum value was recorded. The timed-up-and-go (TUG) (Podsiadlo & Richardson, 1991) test was performed twice to measure functional balance, and the minimum time needed to carry out the task was recorded. Preferred and maximum walking times were measured to evaluate walking ability (Shinkai, Watanabe, & Kumagai, 2000). Subjects were asked to walk a 11-m track; the time taken to walk along the middle 5 m of the track was recorded. The subjects performed the test twice, and the minimum time was recorded. These tests were used because of their reported reliability and convenience. Because our future goal is to validate and disseminate this methodology, we decided to use a simplified protocol and low-cost equipment. All assessments were performed by trained physical therapists and research assistants.

### 2.3. Exercise intervention protocol

Exercise intervention was conducted at a public gymnasium. The protocol included progressive resistance training and balance training performed in accordance with the American College of Sports Medicine guidelines (American College of Sports Medicine et al., 2009) and other related sources (Evans, 1999; Daniels, van Rossum, de Witte,