

## Muscle Strength of Lower Extremities Related to Incident Falls in Community-Dwelling Older Adults

Maki Aoyama<sup>1,2\*</sup>, Yusuke Suzuki<sup>3</sup> and Masafumi Kuzuya<sup>2</sup>

<sup>1</sup>Department of Physical Therapy, Faculty of Health and Medical Sciences, Tokoha University

<sup>2</sup>Department of Community Healthcare and Geriatrics, Nagoya University Graduate School of Medicine

<sup>3</sup>Department of Comprehensive Community Care Systems, Nagoya University Graduate School of Medicine

### Abstract

**Aim:** In order to propose rehabilitation strategies for the reduction of falls risk, thereby preventing falls in older adults, the present study aimed to examine the associations between muscle strength of lower extremities and actual incidence of falls during the 24 weeks follow-up period.

**Methods:** Ninety-nine patients who were attending geriatric outpatient clinic participated and were subjected for analysis. All participants were assessed their physical performances using Motor Fitness Scale and Timed Up and Go test. Muscle strengths of lower extremities were also measured. Incident falls of the participants during the 24 weeks follow-up period were recorded.

**Results:** A binary logistic stepwise regression analysis incorporating all the possible variables into the model revealed that sex (being female) was predictive of frequent falls. Based on the results, the subgroup analysis focusing only on female participants (9 multiple fallers and 49 non-multiple fallers) was carried out using the same definition used in the initial analysis. The results indicated that no lower muscle strengths explained the number of falls in non-multiple fallers, whereas in multiple fallers, plantar flexor muscle strength significantly predicted incident falls during the observation period.

**Conclusion:** Our findings suggested that a standard assessment of muscle strength is a useful component in the risk assessment of falls in a sample of community-dwelling older patients. In particular ankle plantar flexor muscle strength was confirmed to be a predictor of falls in older female patients, therefore might be crucial in considering effective rehabilitation program to prevent falls.

**Keywords:** Lower extremity muscle strength; Incident falls; Fall risk assessment; Older women

### Introduction

Under the circumstance of rapid aging of the society in Japan, health status of older population has become a matter of urgent concern, not just in the framework of healthcare system, but from socio-economic aspects.

In Japan, “bed-ridden older persons” remain a major medical and social problem. A survey showed that 12% of bed-ridden state of older adults occurred as a consequence of falls and related injuries, which are the second greatest causes after stroke [1]. Therefore greater attention has been directed to falls and their prevention.

One in three persons over 65 years of age and almost half of those who were over 80 years of age reportedly fell at least once a year [2]. The chance of recurrent falls increases with advancing age and it was reported that 8-17 percent of those who were 75 years or older [1] sustained multiple falls [2-5]. Consequences of falls include hip fractures, soft tissue injuries [6-9], fear of falling [9], hospitalization, increased immobility and greater disability [7]. Furthermore, falls can lead to loss of self-confidence in one’s ability to perform routine daily tasks, eventually relate to the occurrence of social withdrawal (commonly termed “post-fall syndrome”)[10]. Likewise, falls lead cause of injury, immobility, disability, psychosocial dysfunction, nursing-home placement, and premature death in older adults.

Various risk factors of falls have been raised based on the results of both retrospective and prospective studies. These factors include age, number of chronic diseases, body composition, muscle strength, functional mobility and performance measures related to balance function [11-13]. Most previous findings related to falls risk have been based on clinical evaluation methods [14] but not many of which were gained from the results of actual physical performance tests [15].

Since falls and its consequences have a major impact on functional prognosis in older population, rehabilitation programs, which aim to reduce the risk of falling by augmenting all contributing factors such

as physical activity and balance have the potential to decrease incident falls, thereby improve functional prognosis of older adults.

We previously investigated physical and self-claimed functional factors related to actual incidence of falls in older female patients attending geriatric outpatient and indicated that “being able to go up and down the staircase” is a significant ADL predictor of falls [16]. In line with our research aims of proposing appropriate rehabilitation strategies for the reduction of falls in older adults, the present study examined the association of lower extremity muscle strengths and physical performances with frequency of falls during the 24-week observation period.

### Methods

#### Subjects

Patients aged 65 years and older, who were attending geriatric outpatient clinic of the Nagoya University Hospital, participated in this study. The study was performed in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of Nagoya University School of Medicine, Japan.

Those who met exclusion criteria; (1) Hospital admission within 6 months, (2) Uncontrolled hypertension, (3) Dementia (Mini-Mental

**\*Corresponding author:** Maki Aoyama, Department of Physical Therapy, Faculty of Health and Medical Sciences, Tokoha University, 1230 Miyakoda-cho, Kita-ku, 431-2102 Hamamatsu, Shizuoka, Japan, Tel: +81 53 428 1231; Fax: +81 53 428 1202 E-mail: [ao.makichan@gmail.com](mailto:ao.makichan@gmail.com)

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State Examination (MMSE) [17]  $\leq 15$ ) (4) Ischemic heart disease or heart failure, (5) Chronic obstructive pulmonary disease, (6) Acute orthopedic pain, presence of neurological disorders, were not included.

Prior to the data collection, all subjects signed an informed consent form that summarized the purpose of the study, explained risks and discomforts, indicated that all information gathered would remain confidential, and assured subjects that they could withdraw at any time. After having obtained informed consent, all subjects were instructed to complete a questionnaire named Fall Risk Index (FRI) [18]. It was designed to assess the risk of falls by scoring, and had 22 items of questions including a question asking about the history of falls in a previous year (full score: 22). Based on the results of a retrospective study that identified five independent risk factors of falls [19], we included subjects who answered “yes” for more than five items of questions in the present analyses. All the participants were confirmed to be able to walk a minimum of 6 meters at a time with or without an assistive device. One hundred and four older patients who were attending geriatric outpatient clinic received full set of assessment at baseline. During the 24-week observation period, five patients dropped out due to unscheduled placement to nursing homes. Eventually, 99 older patients who completed 24-week follow-up were subjected for analysis.

In accordance with established guideline which identified history of multiple falls as a potential risk of subsequent falls [20], we divided the study group into multiple fallers, who were defined as those who fell twice or more during the 24 weeks observation period versus non-multiple fallers who were defined as those who did not fall or fell only once during the 24 weeks observation period in our prospective analyses.

All the participants had their medical background obtained by asking existing or previous history of illness, number of medications, type of drugs used, existing physical complaints and geriatric syndromes. They were then subjected to the assessments of physical performance and muscle strength. Detailed descriptions of the assessments are provided as follows.

### Evaluation of Physical Performance

The Motor Fitness Scale (MFS) [21] and Timed Up and Go test (TUG) [22] were used to evaluate physical performance of the participants. MFS was created by totaling the scores for each item on the questionnaire, consisting of 14-item questionnaire on motor fitness. This scale has a unidimensional structure with three subscales, mobility, strength and balance. TUG was designed as a quick measure of basic mobility skill in elderly people. The time taken for subjects to rise from a chair, walk 3 meters, and return to the chair is measured in seconds, with a shorter time taken indicating better mobility. Each subject was asked to perform two test trials and the mean score was recorded.

### Measurement of Muscle Strength

The muscle strengths of lower extremities (hip flexor, knee extensor, ankle extensor and flexor) were measured using a hand-held dynamometer (EG-220, EG-230, SAKAI, Japan), as the strength expressed in Newton (N). No practice was allowed before measurements except that oral instruction was given prior to the trials. Only one attempt providing verbal encouragement was made for both sides, and the mean of both sides was used for analysis in order to dilute the influence of dominant side. All the participants had no history of medical conditions that may affect muscle strength such as overt osteoarthritis or stroke.

Participants were allowed to take rest between the tests as necessary. Time to complete the interview and testing procedures ranged from 40 to 60 minutes.

### Falls Record

Based on a definition of falls as ‘an unintentional change in body position resulting in contact with the ground or with another lower level, however not as a result of a major intrinsic event (e.g. stroke, syncope) or an overwhelming hazard (e.g. car accident)’ [23]. All the participants were given “falls diary”, where incident falls during the 24 weeks observation period were recorded. The diary was collected at the end of follow-up period for counting the number of falls subjected for analysis. All falls are recorded by the participants or their informants if necessary.

### Statistics

The statistical analyses were performed using SPSS (version 18.0) to investigate the association between the parameters and actual incidence of falls.

Before constructing multivariable model for the prediction of falls, univariate analysis was performed across all the variables. P-values and odds ratios (OR) with their 95% confidence intervals (CI) of all variables at baseline were calculated for multiple fallers (MF) versus non-multiple fallers (NMF) to examine statistical significance.

They were combined in a binary logistic regression analysis in which multiple fallers (MF) and non-multiple fallers (NMF) formed a group criterion, as dichotomous dependent variables in order to analyze which tests or other independent variables predict falls. History of falls, sex, age and physical performance score (MFS and TUG) were included as independent variables in the logistic regression. Logistic stepwise regression analysis was also performed to determine which parameter can predict falls with significance after adjusting for covariates. There is no doubt that muscle in the lower extremities play important roles in gait functions, thereby affect occurrence of incident falls. In order to examine the involvement of lower muscle strength in incident falls, age and lower muscle strength (hip flexor, knee extensor, ankle dorsiflexor and plantar flexor) were put into a multiple regression analysis.

All the medical and pharmaceutical information were supplied by participants’ attending geriatricians, and all the assessments were carried out by the same physiotherapist.

### Results

The characteristics of the participants at baseline are presented in Table 1. Univariate analysis between multiple fallers (n=14) and non-multiple fallers (n=85) was performed across all the variables before constructing multivariable model for the prediction of falls (Table 2). All the variables that showed statistical significance in the univariate analysis, which were history of falls, sex, MFS, TUG and those of our interest (age) were forced into a binary logistic regression analysis to predict recurrent falls during the observation period (Table 3). The analysis showed that sex was the only statistically significant variables that distinguished multiple fallers from non-multiple fallers.

Based on the present results, we focused on female participants for further analysis. They were divided into multiple fallers (n=9) and non-multiple fallers (n=49) using the same definition used in the initial analysis. Non-multiple fallers were further divided into those who fell only once (n=16) and those who never fell (n=33) during the observation period. Between the two subgroups of non-multiple

Category	Variable	All(n=99)Proportion (%) or mean ± SD	MF (n=14)Proportion (%) or mean ± SD	NMF (n=85)Proportion (%) or mean ± SD
General:	History of falls (%)	63.6	85.7	58.8
	Event of falls during the observation period (%)	35.4	100	23.5
	Fall Risk Index (FRI)	11.9 ± 3.4	12.1 ± 4.4	11.9 ± 3.2
	Sex female / male (%)	57.6 / 42.4	57.1 / 42.9	57.6 / 42.4
	Age (years)	80.3 ± 5.7	82.0 ± 4.9	80.0 ± 5.8
Physical performance:	Motor Fitness Scale (MFS)	6.5 ± 3.9	5.9 ± 4.6	6.6 ± 3.8
	Timed Up and Go test (TUG) (sec.)	15.3 ± 7.8	17.0 ± 8.1	15.0 ± 7.8
Muscle Strength:	Hip flexion strength (N)	21.1 ± 9.4	21.8 ± 10.1	21.0 ± 9.3
	Knee extension strength (N)	11.2 ± 5.3	11.0 ± 5.7	11.2 ± 5.3
	Ankle dorsiflexion strength (N)	21.6 ± 5.9	21.8 ± 5.9	21.6 ± 6.0
	Ankle plantar flexion strength (N)	29.2 ± 19.6	24.2 ± 15.1	30.1 ± 20.1

SD, standard deviation; N, Newton

**Table 1:** Comparison of variables between multiple fallers (MF: n=14) and non-multiple fallers (NMF: n=85).

Category	Variable	p-value	OR	95%CI	
				Lower	Upper
General:	History of falls (%)	0.043	2.618	1.032	6.643
	Fall Risk Index (FRI)	0.161	1.123	0.955	1.320
	Sex female / male (%)	0.027	3.879	1.170	12.861
	Age (years)	0.098	0.927	0.847	1.014
Physical performance:	Motor Fitness Scale (MFS)	0.019	0.864	0.765	0.976
	Timed Up and Go test (TUG) (sec.)	0.024	1.093	1.012	1.182
Muscle strength:	Hip flexion strength (N)	0.471	0.983	0.939	1.030
	Knee extension strength (N)	0.618	0.980	0.905	1.061
	Ankle dorsiflexion strength (N)	0.273	0.961	0.894	1.032
	Ankle plantar flexion strength (N)	0.127	0.982	0.959	1.005

OR, odds ratios; CI, confidence interval; N, Newton

**Table 2:** Univariate analysis between multiple fallers (MF: n=14) and non-multiple fallers (NMF: n=85).

IndependentVariables	p-value	OR	95%CI	
			Lower	Upper
History of falls	0.378	1.712	0.518	5.567
Sex ( female (vs. male))	0.029	4.063	1.154	14.301
Age	0.069	0.917	0.835	1.007
Motor Fitness Scale	0.415	0.931	0.785	1.105
Timed Up and Go	0.614	0.981	0.909	1.058

dichotomous dependent variable, multiple falls / non-multiple falls

OR, odds ratios; CI, confidence interval

**Table 3:** Binary logistic regression analysis to predict recurrent falls during the observation period (n=99).

fallers, there was no difference in MFS, TUG and the strength lower extremities, only showing a trend that the strengths of knee extension, ankle dorsi and plantar flexor muscle in participants who never fell were slightly greater than those of single fallers.

In order to investigate the involvement of lower muscle (hip flexor, knee extensor, ankle dorsiflexor, ankle plantar flexor) strength in incident falls, a multiple regression analysis was performed making age and lower muscle strengths independent variables and examined whether lower muscle strength can explain number of falls during the observation period. Before analysis, variance inflation factor (VIF) for each independent variable was calculated and confirmed that there were no multicollinearity for all the variables in female multiple fallers, meanwhile in female non-multiple fallers, multicollinearity was observed between hip flexor and ankle dorsiflexor strength, therefore

not included in multiple regression analysis.

The results indicated that no lower muscle strengths explained the number of falls with significance in female non-multiple fallers (Table 4), whereas in female multiplefallers, ankle plantar flexor muscle strength had a significance of predicting falls during the observation period (p<0.013) (Table 5).

## Discussion

In the current study we investigated factors related to actual incidence of falls with particular focus on muscle strength of lower extremities in older adult patients, who were attending geriatric outpatient clinic. Because all the participants enrolled had more or less chronic medical conditions, which may have increased the risk of falls, the results obtained may not necessarily be generalized to healthy community-dwelling older adults. Nonetheless our results are in keeping with findings of a previous report that women had a higher risk of falling than men [24]. Various intrinsic factors such as history of osteoporotic fracture after menopause and lower muscle strength may be involved to explain why women are more susceptible to incident falls than men. Differences in muscle strength and body composition are known to exist between men and women, and from early adulthood on,

Independent Variables	R <sup>2</sup>	p-value	OR	95%CI	
				Lower	Upper
Age	0.249	0.488	1.103	-2.227	1.223
Knee extensor strength		0.289	1.547	-0.835	2.263
Ankle plantar flexor strength		0.597	0.968	-0.853	0.546

dependent variable, Number of falls during the observation period

OR, odds ratios; CI, confidence interval

**Table 4:** Multiple regression analysis for female non-multiple fallers (n=49).

Independent Variables	R <sup>2</sup>	p-value	OR	95%CI	
				Lower	Upper
Age	0.124	0.570	0.967	0.862	1.085
Hip flexor strength		0.081	0.830	0.674	1.023
Knee extensor strength		0.080	1.340	0.966	1.859
Ankle dorsiflexor strength		0.145	1.162	0.949	1.423
Ankle plantar flexor strength		0.013	0.910	0.845	0.980

dependent variable, Number of falls during the observation period

OR: Odds Ratios; CI: Confidence Interval

**Table 5:** Multiple regression analysis for female multiple fallers (n=9).

women have, on average, 30% to 40% less muscle strength than men [25].

Older women are prone to suffer from postural abnormality mainly caused by osteoporotic vertebral fractures. A previous report has demonstrated that vertebral fractures increase fall risk [26]. Loss of spinal flexibility can lead to characteristic flexed or stooped posture [27,28]. In such cases, the pelvis is tilted backward and knee joints are flexed in order to maintain balance. Sakamitsu et al. reported as the trunk inclined forward, functional balance and walking ability declines [29]. Such age-related postural changes more prevalent in females may explain observed higher risk of incident falls in female participants of the present study.

The present results showing that ankle plantar flexor strength can predict the incidence of falls has clinical relevance, given that ankle joint is critical for postural control and one of the main functions of ankle plantar flexor muscle is to stabilize knee joints in extended position [30], thereby contribute to the stability of posture while standing or walking. The results indicated that ankle plantar flexor strength is a risk for female multiple fallers. Declined muscle function in the lower extremities has been identified as one of the risk factors for falls in older adults [20]. Ideal standing and walking must be accomplished efficiently and safely with less fatigue in terms of preventing incident falls and related injuries. Thus the results may suggest measuring the muscle strength of ankle flexors can be used as a sentinel index suggesting necessities for further functional assessments. It also has important implications for clinicians in view of planning effective rehabilitation program for the prevention of falls in older adults.

The involvement of ankle plantar flexor muscle strength in incident falls is in keeping with previous findings by Bendall et al. [31] in which ankle plantar flexor was found to be a predictor of gait speed in a group of 125 men and women aged 65 to 90 years but does not necessarily agree with findings in other reports [32,33] which emphasized the importance of ankle dorsiflexors. As aforementioned, one of the functions of ankle plantar flexor is to stabilize knee joints in extended position. Ankle plantar flexors contribute to the support moment in the stance phase of gait and the plantar flexor moment of the push-off phase of the gait cycle, resulting in a high level of plantar flexor activity with each step [34]. Thus, it is not surprising that the muscle strength of ankle plantar flexors affects gait speed. It is well-understood that ankle plantar flexor not only functions for ankle joint but contributes to maintain stability of knee joint. Hence, for older adults whose muscle strengths for knee extension are decreased, the present results suggested the importance of strengthening ankle plantar flexor, which is activated throughout most of the stance phase in a gait cycle.

Taken all the findings of the present study together, exercises intended to strengthen ankle plantar flexors as well as ankle dorsiflexors may be considered when planning appropriate rehabilitation programs for preventing falls. The previous study that biofeedback-based exercise in community-dwelling older adults reported in a significant improvement in lower extremity muscle strength [35]. In terms of exercise adherence, the subjects who participated in biofeedback-based exercise reported the training to be highly motivating and indicated interests.

Maintenance of physical activity throughout life reduces the prevalence of functional limitations that might closely related with ageing process [36-39]. It may also be expected to increase self-esteem and confidence in one's own abilities to perform physical activities, thereby avoid social withdrawal. Increasing physical activities in daily

life appears to be a simple and effective means of counteracting fall risk factors however, effective protocol of rehabilitation program has not been well-established. Therefore we believe the present results provided some suggestions in considering effective prescription for muscle strengthening in older adults.

Limitations of the current study are as follows. Firstly, there may be some uncertainties about the validity and reliability of self-reported falls even with falls diary provided with sufficient instruction for use. The reliability of fall questionnaire, in particular a possible involvement of recall bias, has been discussed by others [40] and such may be the case with the present study. Secondly, the sample size was relatively small. The scale might perform differently in other populations. Longitudinal data are required to address this issue more carefully. Also a longer period of observation involving more participants would be warranted. Thirdly, in the current study, subjects with significant depressive symptoms and those scoring lower than 15 at the MMSE were excluded in order to endorse the reliability of a series of assessment and falls report if they ever occurred. Although the physical performance in these subjects remains unknown but might have affected the outcomes if they were included.

In conclusion, despite limitations raised above, our findings indicate that a standard assessment of ankle muscle strength is a useful component in the risk assessment of falls in a sample of community-dwelling older patients who were attending geriatric outpatient clinic. The results also suggested that ankle plantar flexor might be a crucial component of lower extremities in planning effective rehabilitation program to prevent falls. Further work investigating the individual effect of specific rehabilitation program on falls prevention in older population would be warranted.

## Conflict of Interest Statement

All the authors declared no conflict of interest.

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