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Rate of torque development and the risk of falls among community dwelling older adults in Japan

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ABSTRACT

Background: Rate of torque development (RTD) is defined as the slope of the torque-time curve obtained during an isometric contraction. Several studies have shown that RTD is lower in fallers than in nonfallers. However, these studies had small sample size and was not adjusted confounding factors.

Research question: Is RTD associated with falls history in healthy community dwelling older adults.

Methods: This was cross-sectional study. In total, 122 participants aged ≥65 (mean, 71.3 ± 4.4) years were recruited for this study. We assessed RTD, muscle strength, functional capacity, and physical activity. We assessed RTD over the first 200 ms of the maximal isometric contraction, whereby the onset of contraction was deemed as the point at which torque had risen 4 Nm above the baseline. Differences between the 3 groups (no fall group, single fall group and multiple falls group) were examined using one-way analysis of variance or Kruskal-Wallis test. A post-hoc Bonferroni or Games-Howell test was used to assess the differences between the individual groups. A multivariate multinomial logistic model was built using the factors associated with the fall category.

Results: RTD was significantly different between the no fall group and multiple falls group (P = 0.047). Similarly, RTD was significantly different between the single fall group and multiple falls group (P = 0.016). RTD was associated with both the no fall group and single fall group (odds ratio = 2.05, 95% confidence interval: 1.06–3.97, odds ratio = 2.45, 95% confidence interval: 1.20–4.98, respectively) in multinomial logistic regression.

Significance: This is the first study to investigate the relationship between RTD and falls history in community-dwelling older adults in multivariate analysis. RTD is more strongly associated with falls history than other performance measures in community-dwelling elderly.

1. Introduction

Falls among elderly people is a major health burden. Each year, approximately 30% of adults aged 65 years or older fall [1]. Not only can falls result in serious injury or death [2], but older adults who experience falls also report increased anxiety and depression and reduced quality of life [3]. Because a single specific cause for falling often cannot be identified, and because falls are usually multifactorial in origin, many investigators have performed both prospective and retrospective epidemiological studies to identify specific risk factors that place individuals at increased likelihood of falling. The prevalence of falls is known to increase sharply with age [4]. Another study showed that falling is associated with muscle weakness (odds ratio [OR] = 4.4), gait disturbances (OR = 2.9), loss of balance (OR = 2.9), visual disturbances (OR = 2.5) and use of psychotropic medication (OR = 1.7). [5] The most important of these risk factors are muscle weakness and problems with gait and balance. The sit to stand activity (30-second chair stand test) or balance ability (One-leg standing test or functional reach test), muscle strength (knee extension strength or grip strength) is used as a functional balance exercise and also is used in this study as a

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screening tool to determine each participant's fall risk [6–9]. These tests, are often useful in identifying risk and documenting need for treatment. The ability to identify these risk factors can guide clinicians or physical therapist to which older adults should receive preventative interventions.

While absolute force production is essential for daily activities, the ability to generate force rapidly is equally important. Previous study showed that the ageing process results in atrophy of the muscles, primarily affecting Type 2 muscle fiber [10]. Type 2 fiber characteristics include short contraction time and the ability to produce. Therefore, with aging the muscles lose their ability for explosive force as a result of the preferential atrophy of these fibers. In order to prevent a falls, force production must occur extremely rapidly [11]. Therefore, not only maximal torque production but also the rate of torque development (RTD) have been identified as key performance characteristics in elderly individuals [12]. RTD is defined as the slope of the torque-time curve obtained during an isometric contraction [13]. Several studies have shown that RTD decreases with aging. Thompson et al. [14] reported that RTD was significantly lower in older adults (n = 18; age = 66.8 ± 4.5years) compared to young adults (n = 25; age = 24.9 ± 3.0years) in univariate analysis. Similarly, Thelen et al. [15] reported that RTD was 25–36% lower in the elderly (n = 24; age range = 65–86 years) than in young adults (n = 24; age range, 19–29 years) in univariate analysis. In addition, the importance of RTD to fall prevention has been reported in the literature. RTD has been reported to be 24–40% lower in fallers than in nonfallers [12,16]. A previous study suggested that the ability to produce torque rapidly may be more important than muscle strength among older adults [12]. Therefore, a decline in RTD may lead to falls in community-dwelling elderly. However, these studies had small sample size and was not adjusted confounding factors. Additionally, because it is likely that age, balance, physical performance and physical activities contribute to falls [17], the contribution of RTD to falls history should be evaluated after adjusting for these potential confounders. The purpose of this study was to investigate the relationship between RTD and falls history in community dwelling older adults in multivariate analysis. We hypothesized that RTD is more strongly associated with falls history than other components of falls history in community-dwelling elderly.

2. Methods

2.1. Participants

This cross-sectional study included 200 community-dwelling adults in Satte city, Japan. The inclusion criteria were age ≥65 years, living in the community, and the ability to walk independently. The exclusion criteria were certification of frailty status by the long-term care insurance service in Japan. An interview was also used to identify those with the following exclusion criteria: severe cognitive impairment; severe cardiac, pulmonary, or musculoskeletal disorders; and comorbidities associated with greater risk of falls, such as Parkinson's disease or stroke. Participants were recruited through an advertisement in the local press. All study procedures were performed in accordance with the tenets of the Declaration of Helsinki and its later amendments, and approved by the institutional review board of Japan University of Health Sciences, Japan (Approval number: 2906-2). Written informed consent was also obtained from all participants.

2.2. Measurement

Outcome measures were evaluated according to data collected from the interview. This interview was used to obtain details of self-reported falls history over the preceding 1 year. This falls history determined participant fall classification. Participants were classified as a multiple faller if they had 2 or more falls in the preceding 1 year. Isometric knee extensor torque during maximal voluntary contraction (MVC) was measured using a hand-held dynamometer (Mobie; Sakai Medical Co., Ltd, Japan, accuracy: ± 2% Rated Output) in the dominant leg (defined as leg used to kick a ball) [18]. Participants were seated on a chair without arm and back support and the hips and knees flexed to 90° (Fig. 1). Participants were asked to push with maximal effort against a cuff positioned just above the talocrural joint. Participants were allowed to lean backward, but not to rise from the seat. This was checked by the investigator and corrected if necessary. Force measures were acquired and passed through an analog to digital converter (Power Lab, AD Instruments, Australia) sampling at 1000 Hz and plotted using LabChart 8 software (AD Instruments, Australia). The distances from the center of the force pad to knee were recorded for each participant and used to convert measured forces into joint torques. The torque values were calculated by multiplying the obtained force values by the distances from the center of the force pad to knee. For muscle strength tests, participants will be allowed 1 warm-up trial. After that, participants performed a total of 2 MVC attempts, each separated by 30 s [19]. MVC was defined as the maximal torque value obtained over the 2 attempts. We assessed RTD over the first 200 ms of the maximal isometric contraction, whereby the onset of contraction was deemed as the point at which torque had risen 4 Nm above the baseline value. RTD was obtained using the following equation [16]:

Fig. 1. Measurement position.

$$RTD = \frac{(Torque_{200} - Torque_{1})}{200ms}$$

The RTD was analyzed at 200 ms from the onset of torque similar to the methods used by Aagaard et al. [20]. The RTD was normalized to body mass as done previously [16]. Time to peak was defined as the time from onset to the greatest torque achieved during the maximal isometric contraction. Grip strength was measured using a Smedley-type hand dynamometer (model TKK5001; Takei Scientific Instruments, Niigata, Japan). Participants were asked to stand themselves with elbows extended at 180°, forearms in a neutral position, and wrists slightly extended. Two measures were taken from the dominant hand, and the highest measure was recorded (kg of force).

Physical function was assessed using the 30-second chair stand test (CS-30), usual gait speed, one-leg standing test (OLST) with eyes open, and functional reach test (FRT). The CS-30 test is a measure of lower-body strength and endurance. Participants were asked to sit in a standard-height chair (42 cm) with their arms crossed over the chest, then stand fully and sit down again as many times as possible within 30 s. Usual gait speed was assessed using a 4-meter walk. In OLST, participants were standing on a flat surface in a well-lit room and asked to stand on one leg for as long as possible. Time was measured using a stopwatch starting when one foot was lifted from the floor and stopped as the elevated foot touched the floor again or the participant touched

any part of the room other than the floor, with any other part of the body. The functional reach test was performed to analyze dynamic balance. Participants were instructed to stand themselves with their lateral body perpendicular to the wall (not touching the wall), feet parallel in a comfortable position, shoulders flexed at 90°, elbows extended, and hands closed. A measuring tape was fixed horizontally on the wall, parallel to the floor, and positioned at the height of the participant's acromion. The initial measurement was taken at the position at which the third metacarpal met the measuring tape. Participants were instructed to lean forward as much as possible without losing balance or taking a step, and the distance was measured as the displacement of the tape from the initial measurement at the third metacarpal to the final measure.

Physical activity was obtained using the Japanese version of the IPAQ (the usual 7 days, short, self-administered version). Data from the IPAQ were summed within each item (i.e., vigorous intensity, moderate intensity, and walking) to estimate the total amount of time spent engaged in physical activity per week. Body composition was measured by bioelectrical impedance analysis (DC-430A, Tanita, Japan).

2.3. Statistical analysis

Data are presented as mean ± standard deviation. Normality of data was assessed using the Shapiro Wilk test. Differences between the 3 groups (no fall group, single fall group and multiple falls group) were examined using one-way analysis of variance or Kruskal-Wallis test. A post-hoc Bonferroni or Games-Howell test was used to assess the differences between the individual groups. For the number of falls, we classified the subjects into a no fall group, a single fall group and multiple falls group, because the characteristics of physical capacity and risk ratio for multiple fallers were different from those of single fallers [21]. In addition, multiple fallers are more likely to experience injury [21]. A multivariate multinomial logistic model was built using the factors associated with the fall category. We analyzed the association between RTD and falls with their odds ratios (ORs) and 95% confidence intervals (CIs). All analyses were performed using SPSS Statistics version 25.0 (IBM Japan Tokyo, Japan). A p value of < 0.05 was considered statistically significant.

3. Results

In total, 200 community-dwelling adults were screened, of which 191 agreed to participate. Fifty-three participants were excluded because they did not match the inclusion criteria. Of the 138 participants, 16 were excluded due to missing data in the assessment. The remaining 122 participants were included in the analysis. The mean age of the participants was 71.3 (standard deviation, 4.4) years, and 50.8% of the participants were women. Table 1 shows the test of homogeneity of variances and normality. Table 2 and Fig. 2 shows the basic characteristics of the participants. RTD was significantly different between the no fall group and multiple falls group ($P = 0.047$). Similarly, RTD was significantly different between the single fall group and multiple falls group ($P = 0.016$). There was a significant difference in time to peak between the single fall group and multiple falls group ($P = 0.035$). There was no significant difference between groups regarding MVC. There were significant differences in height, weight, BMI, MVC/kg, RTD/kg, grip strength, OLST and physical activity between men and women ($P < 0.001$, $P < 0.001$, $P = 0.016$, $P < 0.001$, $P = 0.040$, $P < 0.0001$, $P = 0.003$, $P = 0.002$, respectively). There were no significant differences in age, time to peak, CS-30, usual gait speed and FRT between men and women ($P = 0.096$, $P = 0.220$, $P = 0.077$, $P = 0.080$, $P = 0.859$, respectively). Table 3 shows the association of independent variables between the different falls groups in multinomial logistic regression. RTD was associated with both the no fall group and single fall group (OR = 2.05, 95% CI: 1.06–3.97, OR = 2.45, 95% CI: 1.20–4.98, respectively).

Table 1
Test of Homogeneity of Variances and normality.

	Shapiro-Wilk test			Levene's test	
	No fall group	Single fall group	Multiple falls group	Levene Statistic	p-value
Age, y	< 0.01	< 0.05	0.55	1.47	0.23
Height, cm	0.27	0.39	0.06	1.08	0.34
Weight, kg	0.55	0.39	0.25	3.23	0.09
BMI, kg/m^2	0.61	0.33	0.06	3.03	0.05
MVC/kg, Nm kg^{-1}	0.36	0.12	0.43	2.43	0.09
RTD/kg, Nm s^{-1} kg^{-1}	0.08	0.09	0.06	3.10	0.05
Time to peak, ms	0.45	0.53	0.48	2.93	0.05
Hand grip strength, kg	< 0.01	0.91	0.34	1.14	0.32
CS-30, number	0.54	0.09	0.49	0.04	0.96
Usual gait speed, m/s	0.45	0.36	0.35	8.35	< 0.001
OLST, s	< 0.01	< 0.01	< 0.01	1.2	0.15
FRT, cm	0.54	0.30	0.25	0.69	0.51
Physical activity, kcal	< 0.01	< 0.01	< 0.01	0.48	0.62

BMI, Body Mass Index; MVC, Maximal Voluntary Contraction; RTD, Rate of Torque Development; CS-30, 30-second Chair Stand test; OLST, One-Leg Standing Test; FRT, Functional Reach Test.

4. Discussion

This cross-sectional study was conducted to investigate the relationship between RTD and falls history in community-dwelling older adults. At present, few studies have reported on the relationship between RTD and falls. The present study first attempted to investigate the relationship between RTD and falls history in community-dwelling older adults in multivariate analysis. This study showed that RTD was associated with multiple falls history in community-dwelling older adults. Moreover, MVC was not associated with single fall history and multiple falls history. The importance of producing muscle force rapidly (i.e., RTD) to fall prevention has been described in previous studies. It allows an individual to react quickly to a postural perturbation and to support their body weight during reactive stepping [22]. Bean et al. [23] and Sayers et al. [24] reported that contraction velocity was a predictor of performance on lower intensity functional tasks than muscle strength. This argument is in line with those proposed by Cuoco et al. [25] that walking tasks are more dependent on speed than strength. Skelton et al. [26] observed a significant difference in RTD between fallers and non-fallers. RTD is a multi-factorial variable. Age-related reduction in RTD is attributable to lower tendon stiffness, slower neuromuscular activation, decreases muscle mass, decreases in the number of fast twitch fibers, increases in fat infiltration within the skeletal muscle and reduced anatomical cross-sectional area [19,27–29]. Klass et al have reported that age-related decline in RTD among older adults coincided with a reduction in motor unit discharge frequency, indicating a diminished capacity for rapid neuromuscular activation [27]. Aging related atrophy and subsequent loss of rapid force generation and functionality may be caused by a loss of muscle fibers and reduction in the size of the type 2 fiber [28]. Bottinelli et al reported that type 2 fibers are capable of producing up to 10–20 times the isometric tension as type 1 fibers, performance of rapid movements may become impaired [29]. There are additional neuromuscular factors which could contribute to the age-related decrease in force output including a reduction in quadriceps peak anatomical cross-sectional area and quadriceps voluntary activation, both of which were lower in the elderly. Probably, RTD influences more the ability of the subjects to recover balance and avoid a fall after tripping than the maximum force capability (i.e., peak torque). Decline in RTD may be caused by decreases muscle mass, decreases in the number of fast twitch fibers, increases in fat infiltration within the skeletal muscle and reduced

Table 2
Characteristics of Study Participants.

	No fall group (n = 88)	Single fall group (n = 24)	Multiple falls group (n = 10)	Total (n = 122)	F(2, 119)	P-value
Age, y	71.3 ± 4.7	71.2 ± 3.7	71.4 ± 2.9	71.2 ± 4.4	0.007	0.99
Female	43 (48.9)	11 (45.8)	6 (60.0)	60 (49.2)	–	0.75
Height, cm	158.6 ± 9.0	159.1 ± 8.7	159.9 ± 7.8	158.8 ± 8.8	0.128	0.88
Weight, kg	57.0 ± 9.3	57.3 ± 10.0	63.6 ± 13.9	57.6 ± 10.0	1.991	0.14
BMI, kg/m^2	22.6 ± 2.7	22.5 ± 2.7	24.7 ± 4.2	22.8 ± 2.9	2.529	0.08
MVC/kg, Nm kg^{-1}	2.1 ± 0.6	2.1 ± 0.7	2.0 ± 0.3	2.1 ± 0.6	0.130	0.88
RTD/kg, Nm s^{-1} kg^{-1}	5.8 ± 2.7*	6.5 ± 3.6*	3.5 ± 2.0	5.7 ± 2.9	4.052	0.02
Time to peak, ms	475.2 ± 260.4	418.0 ± 226.1*	705.4 ± 619.8	482.9 ± 303.3	3.395	0.04
Hand grip strength, kg	30.4 ± 7.3	30.8 ± 6.6	31.6 ± 8.3	30.6 ± 7.2	0.136	0.87
CS-30, number	22.1 ± 7.5	22.6 ± 6.6	19.6 ± 7.6	22.7 ± 7.3	1.051	0.35
Usual gait speed, m/s	1.37 ± 0.19	1.31 ± 0.18	1.37 ± 0.36	1.36 ± 0.20	0.972	0.38
OLST, s	82.4 ± 41.8	93.0 ± 41.3	80.1 ± 51.6	84.3 ± 42.4	0.641	0.53
FRT, cm	39.0 ± 6.5	38.5 ± 7.1	36.6 ± 8.7	38.7 ± 6.8	0.553	0.58
Physical activity, kcal	514.1 ± 619.6	487.7 ± 453.5	595.7 ± 992.5	515.6 ± 623.8	0.105	0.90

Data are presented as mean ± SD. *Significantly different from multiple falls group. BMI, Body Mass Index; MVC, Maximal Voluntary Contraction; RTD, Rate of Torque Development; CS-30, 30-second Chair Stand test; OLST, One-Leg Standing Test; FRT, Functional Reach Test.

anatomical cross-sectional area in the present study. There was significant difference in knee joint extension RTD between the no fall group and the multiple falls group in the present study. Similarly, there was significant difference in knee extension RTD between the single fall group and the multiple fall group. These finding conflicts with previous study [12]. One reason for this may be that the participants were only women in the previous study. Yamada et al. [30] reported that the prevalence of sarcopenia (i.e. decrease muscle mass and muscle strength) was higher in women than in men (65–69 years: OR = 4.81, 95% CI = 1.12–20.55; 70–74 years: OR = 2.41, 95% CI = 1.18–4.91) in those younger than 75 years. Approximately half of the participants were male in the present study and mean age was higher in the present study (mean age, 71.3 years) than in Bento et al's study [12] (mean age, 67.3 years). There was not significant difference in knee joint extension RTD between the no fall group and the single fall group in the present study. Previous studies showed that RTD was significantly lower in fall group compared to no fall group [16]. Another study showed that knee extension RTD was not significant differences between no fall group and single fall group [12]. In elderly population, multiple risk factors have been shown to be associated with falls, including impaired balance or gait [31], visual impairment [32], chronic disease [33], medication use [34], and frailty [35]. Falls are also associated with psychological factors [36] and socioeconomic factors [37]. In present study, other factors(e.g. frailty or psychological and socioeconomic factors) may be associated with single falls.

In the present study, 27.9% of the participants had experienced a fall at least once during the year. Previous studies showed that the fall rate among the elderly was 28–35% during a year [38,39]. In Japan, Takazawa et al. [40] reported that the fall rate among community-dwelling elderly (median age, 80 years) was 49.0% during a year. Similarly, 8.9% of the participants had experienced multiple falls in the present study. A previous study reported that the multiple falls rate was 26.0% during a year [40]. Another study showed that the multiple falls rate was 10% among community-dwelling elderly [41]. Our results were much lower than reported in other studies in Japan. One reason for this may be that our study participants were younger (mean age, 71.3 years) and healthy (mean physical activity, 515.6 ± 623.8 kcal).

Muscle strength was not associated with falls history in the present study. Many studies have assessed the relationship between lower muscle strength and falls. Several studies suggested that lower muscle strength was associated with falls. Davis et al. [42] studied fall-related factors among 705 older Japanese women (mean age, 74 years) living in Hawaii. The age-adjusted rate ratios associated with lower isometric quadriceps strength was 1.5 for a first fall, 1.2 for a second fall, and 1.5 for a third fall. The isometric strength of the quadriceps (knee extensors) was measured using a leg extension chair designed for strength testing and hand-held dynamometer. Another study showed that the isometric forces of knee extension and ankle dorsiflexion using hand-

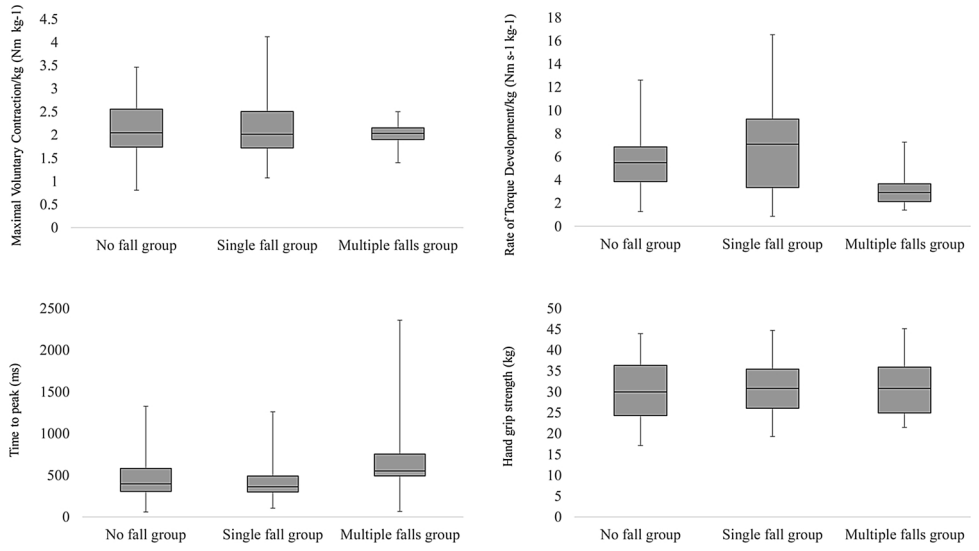

Fig. 2. Maximal voluntary contraction, rate of torque development, time to peak and hand grip strength in elderly participants with no fall, single fall and two falls.

Table 3
The association of independent variables between the different falls groups: multinomial logistic regression.

	No fall group (n = 88)				Single fall group (n = 24)				Multiple falls group (n = 10)
	OR (95%CI)	β	Standard error	P-value	OR (95%CI)	β	Standard error	P-value	
Intercept		3.90	10.1			3.36	11.2		
Age, y	1.05 (0.86-1.29)	0.05	0.10	0.63	1.08 (0.86-1.35)	0.07	0.12	0.53	Reference
Male	0.48 (0.01-18.98)	−0.50	1.89	0.79	0.09 (0.01-6.85)	−2.00	2.2	0.28	Reference
BMI, kg/m^2	0.79 (0.55-1.13)	−0.23	0.18	0.19	0.71 (0.48-1.05)	−0.34	0.20	0.09	Reference
Muscle mass, kg	0.95 (0.76-1.15)	−0.05	0.10	0.60	1.06 (0.83-1.36)	0.06	0.13	0.64	Reference
MVC/kg, Nm kg-1	0.65 (0.32-1.31)	−1.28	1.14	0.23	0.51 (0.23-1.15)	−2.0	1.3	0.10	Reference
RTD/kg, Nm s-1 kg-1	2.05 (1.06-3.97)	0.72	0.34	0.03	2.45 (1.20-4.98)	0.90	0.36	0.01	Reference
Time to peak, ms	1.00 (0.99-1.00)	0.001	0.001	0.82	1.00 (0.99-1.00)	0.001	0.002	0.72	Reference
Hand grip strength, kg	1.10 (0.88-1.36)	0.09	0.11	0.40	1.10 (0.87-1.42)	0.1	0.13	0.41	Reference
CS-30, number	1.12 (0.95-1.30)	0.11	0.08	0.15	1.12 (0.95-1.32)	0.11	0.08	0.19	Reference
Usual gait speed, m/s	0.32 (0.01-31.00)	−1.18	2.3	0.63	0.02 (0.01-3.80)	−3.9	2.6	0.15	Reference
OLST, s	0.99 (0.96-1.01)	−0.01	0.01	0.24	0.99 (0.97-1.02)	−0.003	0.01	0.82	Reference
FRT, cm	0.99 (0.86-1.13)	−0.01	0.07	0.90	0.97 (0.83-1.13)	−0.04	0.08	0.67	Reference
Physical activity, kcal	1.00 (0.99-1.00)	0.000	0.001	0.96	1.00 (0.99-1.00)	0.000	0.001	0.85	Reference
Test						χ2	df	P-value	
Overall model evaluation									
Likelihood ratio test						27.6	26	0.38	
Goodness-of-fit test									
Pearson						206.0	216	0.68	

BMI, Body Mass Index; MVC, Maximal Voluntary Contraction; RTD, Rate of Torque Development; CS-30, 30-second Chair Stand test; OLST, One-Leg Standing Test; FRT, Functional Reach Test; OR, odds ratio; 95%CI, 95% Confidence interval.
Variance Inflation Factors: Age, 1.19; Male, 5.31; BMI, 1.61; Muscle mass, 5.14; MVC, 3.04; RTD, 3.42; Time to peak, 1.93; Hand grip strength, 4.00; CS-30, 1.29; Usual gait speed, 1.43; OLST, 1.395; FRT, 1.29; Physical activity, 1.21. $R^2 = 0.26$.

held dynamometer had a strong relationship to falls among disabled elderly after controlling for age [40]. On the other hand, a few studies reported that lower muscle strength was not associated with falls. Lord et al. [43] reported that the knee extensor muscle strength using a spring gauge dynamometer of recurrent fallers was significantly weaker than that of non-fallers and single fallers in a univariate analysis. This study reported that there was no significant correlation between lower muscle strength and falls. In addition, Campbell et al. [39]. suggested that lower isometric knee extensor strength using an electronic dynamometer did not have a significant correlation with fall status after controlling for age. These studies suggested that age was major risk of falls in community dwelling adults. MVC may be less sensitive to altered neural or muscular capability because they are predominantly force-dependent. Several studies reported that maximal contraction velocity under unloaded or isotonic resistance conditions is considerably slowed with aging [22,44] and may be a key component in the onset of functional difficulties in the elderly [45]. Indeed, power has been shown to decline earlier and more rapidly than strength with advancing age [46]. Therefore, it may be necessary to measure RTD in healthy community-dwelling elderly.

The present study had some limitations. First, hand-held dynamometer is not comparable to complete and corrected biomechanical measurement. Previous studies showed that many sources of error in joint moment calculation exist when using Biodex-dynamometer or other similar devices [47,48]. Second, we did not measure the environmental factors and cognitive function, which is an important factor for falls history. Several studies have reported relationships between falls and outdoor settings, cognitive function, and eyesight. Third, we evaluated the number of falls by interview, which is not as accurate as a fall diary. A previous study pointed out that the elderly, especially those with impaired mental status, often forget recent falls [49]. On the other hand, another study reported that fall interviews for elderly women showed enough reliability [50]. It is possible that we could not eliminate the misclassification of the fall status completely. However, the misclassification is thought to be nondifferential, and therefore the direction of the effect may be an underestimation of risk ratios. Third, we did not measure other lower limb muscle of RTD. A previous study showed that other lower limb muscle were associated with falls [12,51].

5. Conclusion

We investigated the relationship between RTD and falls history in healthy community-dwelling older adults. This is the first study to investigate the relationship between RTD and falls history in community-dwelling older adults in multivariate analysis. We found that lower RTD was associated with multiple falls history. In contrast, muscle strength was not associated with multiple falls history in healthy community-dwelling older adults. These findings suggest that RTD is more strongly associated with falls history than other performance test in community-dwelling elderly.

Conflicts of interest

The authors declare no conflicts of interest.

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