

Decreased Time on the Nondominant One-Leg Standing Test Associated with Repeated Falls in Older Residents with Healthy Aging, Mild Cognitive Impairment, and Dementia: The Wakuya Project

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Keywords

Older adults/people/persons · Mild cognitive impairment · Nondominant leg · One-leg standing · Repeated falls

Abstract

Introduction: The aim of this study is to clarify the association between repeated falls and the dominant/nondominant side in the open-eyed one-leg standing (OLS) test among people who are healthy or have mild cognitive impairment (MCI) or dementia in a community setting. We recruited 180 participants from 39 areas in the town of Wakuya.

Methods: This is a cross-sectional study. Participants were classified into 3 Clinical Dementia Rating (CDR) groups, i.e., CDR 0 (healthy, $n = 71$), CDR 0.5 (MCI, $n = 85$), and CDR 1+ ($n = 23$), and they were investigated for motor function (grip strength, 6-m normal gait speed, timed up and go test, and OLS test) and falls during the past year. **Results:** Subjects with a CDR of 0.5 had higher rates of single and repeated falls (13.0 and 23.4%, respectively) than the CDR 0 group (12.1 and 4.5%, respectively), as did those in CDR 1+ group (15.0 and 30.0%). For the CDR 0.5 group, the frequency of falls was

negatively (biologically meaningful direction) correlated with the left OLS time. No significant correlations with falls were found for other motor function tests. Another analysis separating the CDR 0.5 group into 2 subgroups (repeated falls vs. no or a single fall) also showed that the left OLS time was lower in subjects with repeated falls. **Conclusion:** People with MCI who had fallen repeatedly in the year before the assessment had a significantly lower left OLS time compared to those who had not fallen or had had 1 fall with MCI. None of the other physical measures were associated with past repeat falls including OLS on the dominant right side. No such findings were noted in the CDR 0 and CDR 0+ groups.

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Introduction

People can learn from accidents and change behaviors to avoid repeating accidents thereafter. However, people with cognitive impairment may repeat the same accidents. People may occasionally fall but should avoid re-

peating falls that can lead to adverse events, such as fractures [1–3]. Previously, people with a Clinical Dementia Rating (CDR) [4, 5] of 0.5 (mild cognitive impairment; MCI) were found to show learning disabilities neuropsychologically [6]. Thus, we have herein paid attention to “repeated falls” and not simply to “a single fall.”

Repeated falls leading to a femoral neck fracture are not only associated with a substantial loss of functional independence but also adversely affect the rehabilitation outcomes of patients with a fracture [7].

Falls are the main cause of fractures [1], resulting in a decreased quality of life for older adults [8]. Quite a few older people suffer falls each year resulting in major injuries such as fractures [9], and thus early detection of older people who are at risk is important, as is the implementation of possible interventions that may preserve their quality of life.

The major risk factors for falls in older adults include gait and/or balance disturbances and muscle weakness [9]. Disturbed balance and motor function tests such as walking speed, grip strength, performance on the timed up and go test (TUG), and walking aid use have been reported to be associated with the risk of falls [10, 11].

In addition to these findings, cognitive impairment, MCI [12], and dementia [13, 14] are associated with falls. Several studies have found that cognitive impairment, especially with regard to processing speed or executive function, is related to falls in older adults [15–18], especially people with MCI; moreover, it has been reported that combined physical and cognitive impairments predict falls better than physical or cognitive impairment alone [19].

Since there are so many older adults who are assessed as having a CDR of 0.5 (MCI) in the community [20], and who show impaired executive functions [21], it is necessary to use a quick, easily understandable method to predict falls.

In this aspect, we have focused on the one-leg standing (OLS) test. It is a simple test that measures the elapsed time standing on one-leg with no support and does not require a large space or any apparatus. According to previous reports, the OLS test is a strong predictor of falls [22, 23].

However, the relationship between the OLS test and falls is still unclear, and positive [14, 24, 25] and negative [26, 27] findings have been reported. This is probably due to the use of different methods. Most OLS tests are performed with the participants having their eyes open [28, 29]. Regarding the choice of leg, Netz and Argov [30] recommended the use of both legs, since they found large

differences depending on the leg used. However, other studies have found no differences between legs [27, 31]. The maximum OLS time used for measurement has been 15 [32], 30 [27], 45 [33], 60 [30] and ≥ 60 s [34, 35], and the frequency of measurement has varied from 1 to 5 times [36], or the best time [27] or the average time from several trials [37] has been used. We used 120 s as our measurement time (see below).

Therefore, the aim of this study is to clarify the associations between repeated falls and the dominant/non-dominant side in the OLS test in healthy people and in those with MCI and dementia in a community setting.

Methods

The Wakuya Project

This study was performed in the town of Wakuya, which is in an agricultural area in the Miyagi Prefecture, in Northern Japan. The population is 16,485, including 2,907 older residents aged ≥ 75 years in 2018. The aim of the Wakuya Project is to investigate physical activity and the association between life style-related diseases and cognitive function in older residents. The number of participants was chosen to give a significant 95% CI with the assumption of a prevalence of dementia of 10–15%.

Participants

A total of 180 participants from 39 areas in Wakuya were recruited, including 80 from 4 areas with low official medical check-up rates and 100 from 13 areas with high medical check-up rates to minimize the effects of the check-up. All of the subjects were right-handed; however, we cannot rule out the possibility that some were born left-handed but were forced to be right-handed in childhood due to sociocultural pressures in the area. The subjects underwent neuropsychological, motor function, and physical examinations, and family members were interviewed about the daily life of each subject, including falls. The severity of dementia was evaluated in a CDR decision conference. People with the following conditions were excluded: (1) paralysis causing severe motility disability (paralysis was defined by the presence of neurological symptoms and significant differences in muscular strength between the left and right arms or legs by measuring the muscular strength of the hands), (2) ataxia due to cerebral or vestibular diseases diagnosed by a neurologist or an otorhinolaryngologist, and (3) an orthopedic disease, diagnosed by an orthopedist, that could affect motor tasks.

Also, public health nurses in the town confirmed the absence of illnesses such as Meniere disease and musculoskeletal disease with reference to physicians' records.

Ethics

An explanation related of this study was given in public halls. After obtaining written consent from each participant, public health nurses visited the participant's home on another day to obtain consent from family members.

Table 1. Demographics of the participants

	CDR 0	CDR 0.5	CDR 1+	χ^2/F value	<i>p</i> value
Subjects (men/women), <i>n</i>	72 (23/49)	85 (39/46)	23 (12/11)	4.46	0.107
Age, years	79.6 (3.6)	80.2 (3.9)	83.0 (4.2) ^{ab}	6.99	0.001
Education, years	11.3 (2.2)	10.6 (2.4)	9.5 (2.5) ^a	5.16	0.007
MMSE score	26.0 (2.5)	23.6 (3.1) ^a	19.5 (3.6) ^{ab}	43.42	0.000

Data are shown as means (SD) unless otherwise stated. Gender did not differ significantly among the groups (χ^2 test). In a one-way ANOVA (Bonferroni post hoc test), age was significantly higher in the CDR 1+ group ($F = 6.993$; $p = 0.001$), years of education was significantly lower in the CDR 1+ group than in the CDR 0 group ($F = 5.161$; $p = 0.007$), and the MMSE score was significant in descending order as follows: CDR 0, CDR 0.5, and CDR 1+ groups ($F = 43.420$; $p = 0.000$). ^a Significant difference vs. The CDR 0 group ($p < 0.05$). ^b Significant difference vs. The CDR 0.5 group ($p < 0.05$).

CDR Assessment

A clinical team of medical doctors and public health nurses determined the CDR while blinded to the results of the Mini-Mental State Examination (MMSE). Before being interviewed by the doctors, the participants were visited in their homes by public health nurses for evaluation of their daily activities. Observations by the family with respect to the participants' lives were obtained using a semi-structured questionnaire. The participants were interviewed by doctors to assess episodic memory, orientation, and judgment. Finally, with reference to the information provided by the family and the public health nurses, the participants' CDR stage was decided at a joint meeting. A reliable Japanese version of the CDR Worksheet [5] was established, and dementia was diagnosed based on the Diagnostic and Statistical Manual of Mental Disorders (DSM)-IV criteria. One of the authors (K.M.) was certified as a CDR rater at the Alzheimer's Disease Research Center Memory and Aging Project of the Washington University School of Medicine. The CDR 0 (healthy), CDR 0.5 (MCI), and CDR 1+ (dementia) groups included 72, 85, and 23 participants, respectively. Dementia was also confirmed using the DSM-IV criteria.

Table 1 shows the demographics of the study population. Gender did not differ significantly among the CDR 0, 0.5, and 1+ groups. The CDR 1+ group was older and had a lower education level, and lower MMSE scores than the other groups.

Falls during the Past Year

A fall is defined by the World Health Organization as an event that results in a person coming to rest inadvertently on the ground or floor or other lower level.

The families of the participants were interviewed about the participants' frequency of falls in the past year. The definition of the FICSIT examination (20:35) was used to define "fall". The frequency of falls per year was defined as follows: one or more as "presence of a fall" and zero as "absence of a fall." Repeated falls per year was defined as follows: 2 or more as "presence of repeated falls" and one or fewer as "absence of repeated falls."

Motor Function Tests

The following tests were performed under careful observation by a physical therapist (K.K.), with occasional resting time.

Open-Eyed OLS Test

After the participant was asked to "put both hands on the waist, raise one leg about 5 cm from the floor, and stand up for as long as possible," a practice test was performed once or twice. The actual test was then performed with the same instructions. The maximum time for standing up was 120 s, and times for the left and right legs were each measured twice. The time was measured until a near fall due to strong swaying, shifting of the standing leg, or setting of the raised leg down on the floor. The average times of the 2 measurements for the dominant leg (right side; all of the participants were right-handed) and the nondominant leg (left side) were used in the analysis.

Walking Speed Test

A run-up path of 1.5 m was placed at the start and end of a 6-m walking track. After the request to "walk at your usual walking speed" was given, the time taken for the test was measured twice using a stopwatch. The average of the 2 measurements was used for the analysis.

TUG Test

A cone was placed 3 m from the front of a chair with a seat height of 40 cm. After the participants were asked to "stand up from a sitting posture on the chair, turn back 3 m from the front of the marked point, and sit down again on the chair," the time taken from the sitting posture to sitting down again was measured. The participants walked at their usual walking speed after receiving an instruction to start the test. The time taken was measured twice using a stopwatch, and the average time of the 2 measurements was used.

Grip Strength

The width of the grip of a grip dynamometer was adjusted to bend perpendicularly at the second joint of the forefinger. The grip dynamometer was gripped in the direction outward from the indicator. The participants were instructed to "keep the grip dynamometer apart from your body and clothes and grip the grip dynamometer with all of your strength. Do not swing the grip dynamometer during gripping." The grip strengths of the left and right hands were alternately measured twice, and the average strength of the 2 measurements was used.

Table 2. Frequency of falls and motor functions for each CDR group

	CDR 0			CDR 0.5			CDR 1+		
	<i>n</i>	<i>R_s</i>	<i>p</i> value	<i>n</i>	<i>R_s</i>	<i>p</i> value	<i>n</i>	<i>R_s</i>	<i>p</i> value
Left OLS time, s	64	-0.07	0.287	70	-0.30**	0.005	19	-0.34	0.079
Right OLS time, s	63	-0.17	0.093	70	-0.14	0.117	19	-0.04	0.438
Walking speed, m/s	64	-0.01	0.471	73	-0.25	0.018	20	-0.12	0.314
TUG test time, s	63	0.11	0.186	73	0.15	0.097	19	0.10	0.348
Left grip, kg	65	-0.16	0.099	73	-0.23	0.026	20	-0.27	0.130
Right grip, kg	65	-0.09	0.234	73	-0.25	0.016	20	-0.14	0.284

Shown are the Spearman rank correlation coefficients between the frequency of falls and the OLS time and various motor functions in each CDR group. There was only a significant correlation between the frequency of falls and the left OLS time in the CDR 0.5 group.

Analyses

Since people with cognitive impairment may repeat the same accidents, we focused on repeated falls, especially in subjects with MCI and dementia (CDR 0.5 or greater; i.e., CDR 0.5+).

Analysis 1: Single and Repeated Falls for Each CDR Group

Association between CDR groups and falls were analyzed using a χ^2 test and ANCOVA.

Analysis 2: Frequency of Falls and Various Motor Functions for Each CDR Group

Spearman rank correlation coefficient analysis was used to analyze associations between various motor functions and the frequency of falls.

Analysis 3: Repeated Falls and Motor Functions for the CDR 0.5+ Group

The CDR 0.5+ group was classified into no or a single fall and repeated falls subgroups. Differences between these subgroups were analyzed using multiple ANCOVA with motor functions as dependent variables and age and gender as covariates.

Results

Figure 1 shows data for single and repeated falls in each CDR group. A χ^2 test and ANCOVA showed a significant difference in repeated falls in the past year among the groups. A post hoc test showed significant differences between the CDR 0 and CDR 0.5 groups and between the CDR 0.5 and CDR 1+ groups.

Table 2 summarizes the Spearman rank correlation coefficients between the frequency of falls and the left OLS time and various motor functions for each CDR group. There was a significant correlation between the frequency of falls and the left OLS time only in the CDR 0.5 group.

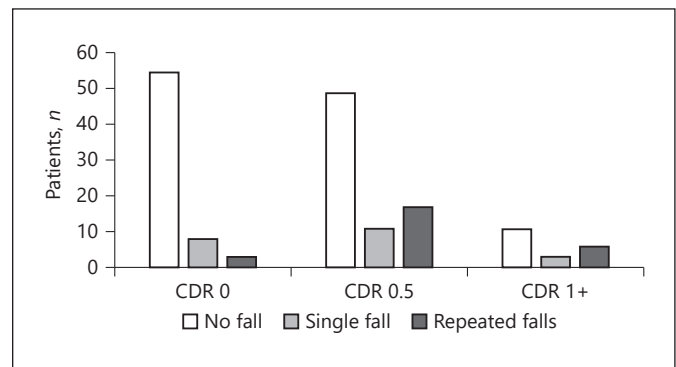


Fig. 1. Prevalence of past falls (none, single, or repeated) by cognitive group (healthy, MCI, and dementia). Single and repeated falls in each CDR group. A χ^2 test showed a significant difference in repeated falls in the past year among CDR groups (value: 11.624; $p = 0.003$). ANCOVA with presence of repeated falls as the dependent variable, the 3 CDR groups as fixed factors, and age and sex as covariates also showed a significant difference in repeated falls among the 3 CDR groups ($F = 5.65$; $p = 0.004$). However, there were no significant differences in age or sex among the groups. Post hoc tests showed significant differences between the CDR 0 and CDR 0.5 groups and between the CDR 0.5 and CDR 1+ groups.

As shown in Table 3, the left OLS time only had a significantly lower value in the repeated falls subgroup compared with the no or single fall subgroup.

Discussion

Limitations

Before discussing the results, we should mention some limitations of this study. First, the sample size (particularly subjects with dementia), was small, resulting in the

Table 3. Repeated falls and motor functions for the CDR 0.5+ group

	No fall or a single fall (<i>n</i> = 67)	Repeated falls (<i>n</i> = 21)	Main effect		Covariant	
			<i>F</i> value	<i>p</i> value	age	sex
Left OLS time, s	12.8 (1.9)	4.5 (3.4)*	4.49	0.037	0.002	0.457
Right OLS time, s	14.1 (2.4)	10.3 (4.4)	0.58	0.450	0.001	0.754
Walking speed, m/s	1.17 (0.03)	1.07 (0.06)	2.38	0.127	0.000	0.013
TUG test time, s	11.1 (0.4)	11.0 (0.7)	0.01	0.939	0.000	0.270
Left grip, kg	21.4 (0.8)	19.4 (1.4)	1.52	0.221	0.005	0.000
Right grip, kg	22.0 (0.7)	21.2 (1.2)	0.34	0.562	0.002	0.000

Values are presented as means (SE). A multiple ANOVA was done, with various motor functions as dependent variables, the presence of repeated falls as a fixed factor, and age and sex as covariants. The left OLS time in the various motor functions showed a significant difference with the presence of repeated falls ($F = 4.491$; $p < 0.05$). * $p < 0.05$.

prediction of very few events. Also, an analysis based on the CDR 0 group versus the 0.5 group versus the 1+ group, together with nonfallers versus the single fallers versus the repeated fallers, needs a 3×3 ANCOVA. Unfortunately, the sample size was small. Further investigations would be needed to clarify these points. Second, although the muscle strength of the legs of all of the participants was neurologically (manually) examined by a neurologist, we did not take objective measures to assess it. This is a community-based study, and we had a time limitation.

Falls of MCI and Dementia

The results of this study showed that the CDR 0.5 and CDR 1+ groups had higher rates of single and repeated falls compared to the CDR 0 group. For the CDR 0.5 group, the frequency of falls was negatively (biologically meaningful direction) correlated with the left OLS time. Another analysis separating the CDR 0.5 group into 2 subgroups (repeated falls vs. no or a single fall) showed that the left OLS time was shorter in subjects with repeated falls. Since falls increased with higher CDR scores, these results support previous findings that MCI and dementia are risk factors for a fall [13, 38, 39].

As earlier described, people can learn from accidents and change behaviors to avoid repeating accidents thereafter. However, people with cognitive impairment may repeat the same accidents. People may occasionally fall but should avoid repeating falls that can lead to adverse events, such as fractures. Previously, people with a CDR of 0.5 (MCI) were found to show learning disabilities neuropsychologically. Herein, we found that people with MCI or dementia cannot learn from the first accident to

avoid a second accident, and their family or caregiver should pay attention in case of repeated accidents, even after having instructed them.

Some of the patients and older residents in the community stated that, “falling means the end.” Clearly, few people want to experience a fall; therefore, people will try to avoid falling if they fall once. If people fall repeatedly, MCI and dementia, and hidden illnesses such as Meniere disease and musculoskeletal disease, may be present; thus, it is important to observe the occurrence of repeated falls. There is also an association between an increased frequency of falls and increased femoral neck fractures, and this also indicates that the frequency of falls and the occurrence of repeated falls are more important than just a single fall.

Nondominant OLS Test

It was of interest that repeated falls only showed an association with the nondominant OLS time. Only left OLS showed any association with repeated falls in the CDR 0.5+ group; thus, there may be an association of repeated falls with a decreased OLS time on the nondominant side in people aged ≥ 75 years. This suggests that the nondominant OLS test may be able to detect CDR 0.5 subjects with a higher risk of falls.

The nondominant side may be important because right-handed people tend to start from the right foot in daily activities such as walking and climbing stairs and in sprints and marathons. With respect to body mechanics, performing an activity with the left leg as the pivot leg is easy for right-handed people. Falls happen due to motor and cognitive decline, drugs, and medical disorders such as dizziness, epilepsy, and stroke. Partial weakening of

support from the nondominant side, i.e., the pivot leg, due to muscle weakness and performance function disabilities as a result of aging among CDR 0.5+ subjects aged ≥ 75 years may also increase the possibility of a fall.

Conclusions

Our results show that a simple OLS test using the nondominant side can identify the risk of a fall. In the community, public health nurses can perform this test for early detection of people at risk for a fall. The test can also contribute to monitoring of treatment after a fall and to prevention of repeated falls.

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Statement of Ethics

Written informed consent was obtained from each of the participants and their families. This study was approved by the ethics committees of the Wakuya government and the Tohoku University Graduate School of Medicine (2014-1-565).

Conflict of Interest Statement

The authors have no conflict of interests to declare.

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Author Contributions

K.K.: data analysis and writing of this paper. K.M.: design, direction, and writing of this paper. M.K., J.T., J.O., and K.N.: data collection.

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