PHYSICAL FUNCTION SCREENING OF INSTITUTIONALIZED ELDERLY WOMEN TO PREDICT THEIR RISK OF FALLING

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Abstract

This study examined the relationship between multiple physical function and falls among institutionalized elderly women, and screening methods designed to effectively identify elderly with a high risk of falling. The subjects comprised 44 elderly women aged 82±6 years residing in a nursing home. Multiple physical assessments were tested using the following measures: muscle strength (quadriceps strength and grip strength), balance test (functional reach and one-legged stance test), flexibility test (sit and reach test), agility test (stepping test), and physical performance test (TUG and chair stand test). Based on the experience of fall-related accidents within the past two years, we categorized the subjects into two groups (non-fall group and fall group). Of these measures, quadriceps strength, grip strength, functional reach, stepping test in a standing position, and chair stand test were significant factors discriminating whether the subject had a history of falls. Logistic regression analysis demonstrated that quadriceps strength, functional reach, stepping test in a standing position, and chair stand test were important predictors of falls in an institutionalized elderly population. The results of this study suggest that 0.84 Nm/kg for quadriceps strength, 2.6 cm for functional reach, 17 steps for stepping test, and 14 sec for chair stand test, were useful indicators for screening institutionalized elderly for risk of falling. Particularly, the stepping test was most effective in screening the elderly to assess their fall risk.


Key word: Elderly, falls, risk factor, physical assessment

I. Introduction

In Japan, with the current sharp increase in the number of elderly aged 65 years or older, the number of fall-related accidents is growing. The consequences of falling include injury, fear of falling, decreased activity, functional deterioration, social isolation, reduced quality of life, and death among elderly persons, particularly among those living in institutions1,2).

Approximately 10~30% of community-living elderly over 65 years old experience falls at least once a year. The incidence of falls among older individuals living in institutions are reported to be about three times that in the community, equating to rates of 1.5 falls per bed per year2,3) or 1.4 falls per person per year4,5). Furthermore, rates of hip fractures as a result of falls in residential care facilities have been estimated to be 10.5 times higher than that in the community5).

The fall of the elderly are usually regarded as a multi-factorial etiological problem, including intrinsic and extrinsic risk factors. Intrinsic risk factors refer to the characteristics of the individual (e.g. dementia, visual impairment, neurological and musculoskeletal disabilities, and postural hypotension). Extrinsic risk factors refer to the environment and surrounding circumstances (e.g. slippery bedspreads and flooring, improper bed height, absence of handrails and inadequate lighting). Generally, the risk of falling

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among community-dwelling elderly who exhibit higher levels of physical fitness and activity tends to be mostly related to extrinsic risk factors. On the other hand, risk factors among residents of care facilities tend to be influenced by physical factors. Physical factors that have been shown to be associated with the risk of falling include a reduced ability to maintain a stance, increased postural sway, reduced dynamic balance, reduced walking speed, decreased mobility, reduced muscle strength, and difficulty rising from a chair. Thus, a great number of studies have shown a significant association between physical measurements and risk of fall. However, there are few good screening tests to estimate risk of falling that can be easily used in a busy clinical setting and quickly predict risk of falling in high-risk populations such as residents of nursing homes. Identifying high-risk populations and remediable risk factors can facilitate tailoring of intervention based on multi-factorial assessment. Furthermore, when choosing an assessment, one must focus not on the single risk factor but must consider the multidimensional factor across various aspects of physical function, because falling in the elderly is typically a multifactorial problem.

Therefore, we focused on multiple physical and functional domains including strength, balance, flexibility, agility, and physical performance. This study identified which of these factors are associated with an increased risk of fall in institutionalized elderly, and examined the thresholds at which translates to an insufficiency increased risk of falling.

II. Methods

A. Subjects

The subjects comprised 44 elderly women, with a mean age of 82 years (SD = 6, range = 68–92) residing in a nursing home in Kyoto, Japan. Therefore, all of these subjects lived under the same environment and surrounding circumstances. The subjects were elderly people who were able to walk independently either with or without a cane. Subjects experiencing difficulties in having their physical function measured due to severe dysfunction such as acute neurological impairment (acute stroke, Parkinson’s disease, and paresis of the lower limbs) or severe musculoskeletal impairment, and subjects with severe dementia (an MMSE score of ten or lower) were excluded from the study.

Based on the experience of fall-related accidents within the past two years, we categorized the subjects into two groups (non-fall group and fall group). The history of falling was ascertained from incident reports kept at the nursing home. Falling was defined as an event which resulted in the person unintentionally coming to rest on the ground or other lower level, but was not caused by a major intrinsic event (such as a stroke).

The subjects were informed about the study procedures before testing and provided a written informed consent before participating. The study was approved by Kyoto University Graduate School and Faculty of Medicine Ethics Committee.

B. Measurements

1. Muscle strength

Quadriceps strength and grip strength were used to represent muscle strength.

Quadriceps strength was measured by a hand-held dynamometer (μ-Tas F-1, ANIMA Co, JAPAN) during isometric contraction for 3 seconds of the knee extensor. With the patient in a sitting position, the hip and knee were at angles of 90°, and the force sensor was placed 10 cm above the lateral malleolus. The maximal isometric strength was determined as the larger value of two repeated measurements after pre-measurement trials with manual resistance. Measurements were obtained bilaterally, and the maximal strength on both sides was used for analysis. Torque was calculated by multiplying strength by the lever arm (distance between the lateral knee joint line and the point of force application) and expressed as a percentage of body weight (Nm/kg).

Grip strength was measured using a handgrip dynamometer (Takei Co, JAPAN) in a sitting position. The subjects, holding with their arms by their sides,
squeezed the handgrip dynamometer with maximum force. The best of two trials was used as the score. Both hands were tested, and the larger value on each side was used for analysis.

2. Balance test

Balance was tested using one-legged stance test (OLST) with eyes open and the functional reach test.

The OLST was performed in the standing position with the subject’s arms by their sides. Timing was begun when the subjects raised one leg. Timing was stopped if the subjects moved the foot they were standing on, touched the suspended foot to the ground, or reached the maximum balance time of 120 seconds. Two trials were performed with the dominant foot if the maximum balance time was not reached on the first trial. The best balance time of the recorded trials was used for analysis.

The testing method for functional reach, the measurement of the distance that the subject was able to reach forward while maintaining a fixed base, has been described by Duncan. He reported that this measure has good predictive validity for recurrent falls and high intertrial and intrarater reliability. The first position of the finger tips was determined, with the shoulder of subject flexed to 90° along a wall. Then subjects were requested to reach as far forward as possible without moving their feet, thus moving their center of gravity forward on the fixed base. Functional reach was defined as the difference between first the finger tip position and that at maximal forward reach.

3. Flexibility test

A sit and reach test was used to measure flexibility. The subjects were seated with their knee joints fully extended and their hip joints flexed about 90° to assume an upright sitting position. They were then asked to bend forward slowly and reach forward as far as possible from this seated position. The score was determined by the distance the subject was able to reach with the fingertips on a scale in centimeters.

4. Agility test

The stepping test in both sitting and standing position was used to measure agility. The subject was asked to step as rapidly as possible, and the total number of steps within 5 seconds was measured using a step counter. The best count of 2 trials was recorded. Test-retest reliability between tests was examined using intraclass correlation coefficients (ICCs). ICCs were 0.91 (95% confidence interval: 0.82–0.95, F=20.2, p<.01) in the sitting position and 0.96 (95% confidence interval: 0.92–0.98, F=50.2, p<.01) in the standing position.

5. Physical performance test

The Timed Up & Go Test (TUG) and chair stand test were used to determine physical performance.

The Timed Up & Go Test (TUG) is used to measure the ability of patients to perform sequential locomotor tasks that incorporate walking and turning. For the TUG, the subject was instructed to stand up from a sitting position in an armless chair, walk a distance of 3 m, turn, walk back to the chair, and sit down. The test was performed once at maximum walking speed, after each subject performed 1 trial to become familiar with the test. The time was measured from the start until the subject sat down in the chair. The participants wore ordinary shoes and walking aids were permitted.

The chair stand test measured the time needed to stand 5 times from a standard chair without using the upper extremities. Subjects were asked to rise to a full standing position and then return back to a seated position as fast as possible. Timing began when the examiner said “Go” and stopped when the subject’s buttocks touched the chair on the fifth repetition. The chairs used were all 46 cm high, armless and had a slightly padded seat.

C. Statistical analysis

Differences in physical measurements between the fall and non-fall groups were examined using student’s t-test (two-sample t-test). When this test
indicated a significant difference, discriminatory analysis was performed to identify the discriminating criteria between these two groups. Univariate logistic regression, using 'faller/non-faller' as the dependent variable, was employed to investigate the relationship of the physical variables. Furthermore, the odds ratios were calculated for each explanatory variable using the cut-off points identified on discriminatory analysis. Finally, multiple logistic regression analysis was run for dependent variable (faller or non-faller) to identify which independent variables (each physical measurement) best predicted the dependent variable. Analyses were performed using SPSS for Windows Version 17.0, SPSS Inc., Chicago, IL and Stat Flex software (Version 5.0, Artec Inc., Osaka). Significance was recognized at p <.05.

III. Results

The fall group consisted of 18 subjects, while the non-fall group consisted of 26 subjects. Table 1 shows the base-line characteristics of the subjects. The background characteristics (age, weight, and height) of the two groups did not significantly differ. In the fall group, none of the subject had a fall that resulted in serious injuries such as fracture, head injuries causing altered consciousness levels, or obviously decreased ability in daily life.

Table 2 shows the mean and standard deviation values of physical measurements between the two groups. The two-sample t-test indicated a significant difference between the two groups in quadriceps strength, grip strength, functional reach, stepping test in a standing position, and chair stand test. There was no significant difference between the two groups in OLST, sit and reach, stepping test in a sitting position, and TUG.

Discriminatory analysis was performed using these five variables that showed significant difference between the two groups. The discriminating criteria between the two groups were 0.84 Nm/kg for quadriceps strength, 13 kg for grip strength, 26 cm for functional reach, 17 steps for stepping test in a standing position, and 14 sec for chair stand test (Tab. 3).

These significant variables were entered into a univariate logistic regression model and the ORs were calculated using the discriminating criteria. Four variables were significantly associated with fallers: quadriceps strength [OR = 5.67; 95% CI = 1.41-22.8] functional reach [OR = 3.78; 95% CI = 1.06-13.4].

Table 1. characteristics of the subjects

<table>
<thead>
<tr>
<th></th>
<th>fall group (n=18)</th>
<th>non-fall group (n=26)</th>
<th>p-value&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>84±7</td>
<td>81±6</td>
<td>.177</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>43.5±7.0</td>
<td>42.3±5.9</td>
<td>.551</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>141.9±7.6</td>
<td>144.1±6.5</td>
<td>.309</td>
</tr>
<tr>
<td>MMSE&lt;sup&gt;b&lt;/sup&gt;</td>
<td>18.3±6.3</td>
<td>21.7±5.4</td>
<td>.186</td>
</tr>
</tbody>
</table>

Data are reported as Mean±SD

<sup>a</sup> compared between fall group and non-fall group.

<sup>b</sup> Mini-Mental State Examination
Table 2. Summary of means and standard deviations of physical measurements

<table>
<thead>
<tr>
<th>Variables</th>
<th>fall group (n=18)</th>
<th>non-fall group (n=26)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle strength</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quadriceps strength (Nm/kg)</td>
<td>0.81±0.33</td>
<td>1.13±0.46</td>
<td>.024</td>
</tr>
<tr>
<td>Grip strength (kg)</td>
<td>11.9±4.1</td>
<td>16.4±7.3</td>
<td>.027</td>
</tr>
<tr>
<td>Balance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OLST (sec)</td>
<td>5.9±6.1</td>
<td>9.7±14.5</td>
<td>.417</td>
</tr>
<tr>
<td>functional reach (cm)</td>
<td>22.8±6.5</td>
<td>28.9±6.7</td>
<td>.005</td>
</tr>
<tr>
<td>Flexibility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sit and reach (cm)</td>
<td>17.8±6.4</td>
<td>19.2±8.8</td>
<td>.563</td>
</tr>
<tr>
<td>Agility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stepping test in a sitting position (steps)</td>
<td>23.4±7.8</td>
<td>27.9±8.6</td>
<td>.117</td>
</tr>
<tr>
<td>Stepping test in a standing position (steps)</td>
<td>14.6±3.2</td>
<td>19.2±7.7</td>
<td>.049</td>
</tr>
<tr>
<td>Physical performance test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TUG (sec)</td>
<td>13.1±5.8</td>
<td>10.4±5.5</td>
<td>.129</td>
</tr>
<tr>
<td>Chair stand test (sec)</td>
<td>17.5±9.3</td>
<td>11.7±4.2</td>
<td>.010</td>
</tr>
</tbody>
</table>

Table 3. Results of discriminatory analysis

<table>
<thead>
<tr>
<th>Variables</th>
<th>linear discriminant function</th>
<th>discriminating criteria</th>
<th>error rate</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quadriceps strength</td>
<td>Z= 3.042X−2.551</td>
<td>0.84 Nm/kg</td>
<td>31.3%</td>
<td>.004</td>
</tr>
<tr>
<td>Grip strength</td>
<td>Z= 0.189X−2.461</td>
<td>13 kg</td>
<td>34.9%</td>
<td>.015</td>
</tr>
<tr>
<td>functional reach</td>
<td>Z= 0.119X−3.115</td>
<td>26 cm</td>
<td>35.6%</td>
<td>.020</td>
</tr>
<tr>
<td>Stepping test in a standing position</td>
<td>Z= 0.159X−2.661</td>
<td>17 steps</td>
<td>32.9%</td>
<td>.011</td>
</tr>
<tr>
<td>Chair stand test</td>
<td>Z=−0.137X+1.966</td>
<td>14 sec</td>
<td>33.0%</td>
<td>.007</td>
</tr>
</tbody>
</table>

stepping test in a standing position [OR = 6.52; 95% CI =1.43–29.7] and chair stand test [OR = 6.67; 95% CI =1.75–25.4] (Tab. 4)

In the multiple logistic regression analysis, the stepping test in a standing position was the only significant predictor of falling (β = 0.46, R² = 0.21, p < .01)

IV. Discussion

Falls are a major contributor to functional decline generally associated with aging. A fall and/or injury can have a devastating effect on the individual’s independence and quality of life, often leading to a spiral of inactivity and further decline. Falls are not always random events and occur, at least in part, because of
physical impairments such as impaired balance, muscular weakness, and slowed reaction time.

Based on many investigations, muscle weakness and poor balance have been well established as risk factors for falls in community-dwelling populations\(^2\). However, there have been few investigations regarding a variety of physical risk factors associated with falls among institutionalized elderly who tend to have a higher incidence of falls caused by physical factors such as muscle weakness and balance impairment. It is necessary to apply a systematic therapeutic approach aimed at identifying and reducing the risk factors of falls multidimensionally in order to prevent falls.

This study examined the relationship of multiple physical risk factors to falls among institutionalized elderly women, and the screening test that can help to identify elderly who are most likely to fall.

Our results showed that both grip strength and quadriceps strength were able to assist in discriminating whether a subject has a high risk of falling, but quadriceps strength had better discriminative properties than grip strength because only quadriceps strength was significantly associated with fallers on univariate logistic regression analysis. It has been reported that the mean score of muscle strength in healthy older adults is about 20%–40% lower than that in young adults, and muscle strength, especially the antigravity muscles of the lower extremities have been shown to decrease rapidly with age\(^9\). It is expected easily that quadriceps weakness due to aging leads to gait disorders, which will subsequently increase the fall risk, especially in frail elderly residing in a nursing home, because many studies have pointed out that quadriceps strength associated with walking ability\(^2\)\(^{10}\). However, there is evidence that older adults, even frail older adults, can improve muscle strength with exercise\(^2\)\(^{11}\)\(^{12}\)\(^{13}\)\(^{14}\). It is considered that establishing minimal strength requirements for the prevention of falls will be a useful index for muscle strength training in the elderly. In this study, discriminative analysis showed 0.84 Nm/kg for quadriceps strength as the discriminating criterion, with a good error rate, as low as 31.3%. These results suggested that this discriminating criterion = 0.84 Nm/kg for quadriceps strength, is a useful indicator for the minimal level needed to prevent falls.

The findings of this study indicate that functional reach test is capable of identifying people with fall risk, but OLST is not associated with risk of falling. Measures of static balance, such as OLST and postural sway during quiet stance do not show substantial declines with age\(^2\)\(^{15}\)\(^{16}\). In contrast, measures of dynamic balance such as functional reach show more marked decline with age, and may more closely approximate challenges to balance in daily life than static measures\(^2\)\(^{17}\)\(^{18}\)\(^{19}\). The findings of this study suggest that dynamic postural control as measured by functional reach is strongly associated with risk of falling, and that 26 cm for functional reach is a useful indicator to identifying nursing home residents at

### Table 4. Univariate logistic regression with faller as the dependent variable

<table>
<thead>
<tr>
<th>Variables (cut-off point)</th>
<th>OR(^a)</th>
<th>95% CI(^b)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quadriceps strength (&lt; 0.84 Nm/kg)</td>
<td>5.67</td>
<td>1.41 – 22.8</td>
<td>0.014</td>
</tr>
<tr>
<td>Grip strength (&lt; 13 kg)</td>
<td>2.33</td>
<td>0.62 – 8.81</td>
<td>0.21</td>
</tr>
<tr>
<td>Functional reach (&lt; 26 cm)</td>
<td>3.78</td>
<td>1.06 – 13.4</td>
<td>0.040</td>
</tr>
<tr>
<td>Stepping test in a standing position (&lt; 17 steps)</td>
<td>6.52</td>
<td>1.43 – 29.7</td>
<td>0.015</td>
</tr>
<tr>
<td>Chair stand test (&gt; 14 sec)</td>
<td>6.67</td>
<td>1.75 – 25.4</td>
<td>0.0055</td>
</tr>
</tbody>
</table>

\(^a\) OR: Odds Ratio.

\(^b\) 95% CI: 95% confidence intervals.
high-risk of falling.

Many previous investigations focus on a measure of protective balance response, rather than corrective
balance response (i.e., stepping performance) as a potential clinical measure of fall risk. The findings of
this study showed that the stepping test in a standing position appears to be a more useful indicator in pre-
dicting falls than the stepping test in a sitting position. Many studies have found that simple reaction
time increases with age\textsuperscript{30, 31}, and that older adults also exhibit slowed voluntary stepping, particularly
when having to change leg\textsuperscript{32–34}. The ability to take a step quickly is important for balance maintenance
during activities of daily living, and for preventing falls when externally perturbed. The results of this
study suggest that stepping test in a standing position as measured ability to take a volitional step
rapidly, is a key factor that distinguishes high-risk population for fall. In this stepping test, 17 steps
according to discriminating criterion may be important predictors to screen quickly for fall risk.

Previous studies have shown that the TUG test is associated with an increased risk of falls in the
community-dwelling elderly\textsuperscript{35–37}, but in our study, the TUG was unable to predict falls in contrast to
these studies. It is noted that various factors, such as impaired cognitive function\textsuperscript{38} and the height
and type of chair used (armrests or not)\textsuperscript{39}, may influence performance on the TUG. In frail nursing home
residents with lower physical fitness and cognitive function than those in community-dwelling elderly, it
is necessary to investigate the measurement condition of TUG in detail.

The results of this study by univariate logistic regression suggest that of the various physical function
assessments investigated, quadriceps strength, functional reach, stepping test in a standing position, and
chair stand test were important predictors of falls in an institutionalized elderly population. In this study,
the results of discriminatory analysis showed 0.84 Nm/kg for quadriceps strength, 26 cm for functional
reach, 17 steps for stepping test, and 14 sec for chair stand test were derived from the linear discriminant
function as the value to identify the elderly with a high risk of falling; the error rate was also satisfac-
tory. Furthermore, this study suggested that these discriminating criteria may be useful indicators of
the minimum level needed to prevent falls, and that decreases in these ability may increase the rates of
fall incidence about 4–7 times.

In nursing care facilities, it is necessary to perform a simple screening test and determine the risk of fall-
ing in a short period of time. While univariate logistic analysis extracted four factors: quadriceps
strength, functional reach, the stepping test, and chair stand test, associated with the risk of falling, multiple
logistic regression analysis suggested that only the stepping test was an influencing factor. The stepping
test is a simple screening method, and its high reproducibility was demonstrated in the present study in-
volving elderly subjects. Previous studies on the relationship between falling and physical function of
elderly people have focused on their muscle strength and balance ability, and there have been few reports
on the relation between agility and falling. The present results indicated that fall-related accidents in
care facilities for the elderly were closely associated with their agility, and 17 steps for stepping test was
identified as an effective indicator to determine the risk of falling.

One of the limitations of this study was that incidence of falls was recorded retrospectively. However,
considering that none of the subject had a fall that resulted in serious injury or had obviously decreased
physical function after a fall, the findings of this study suggested that quadriceps muscle weakness,
poor dynamic balance, poor stepping ability, and poor standing ability are significant and consistent risk
factors in institutionalized elderly people. Another limitation of the present study was as follows: only a
small number of people participated in the study, and all subjects were frail institutionalized elderly women
without severe dementia. We need to conduct further research, using a larger number of samples, to vali-
date the effectiveness of the screening method in determining the risk of falling among elderly with se-
vere dementia and those dwelling community who exhibit higher levels of physical fitness and activity.

V. Conclusions

The aim of this study is to examine the relationship between multiple physical domains and falls, and screening tests to identify institutionalized elderly at high risk of falling. The results of the present study demonstrated that the discriminating criteria - 0.84 Nm/kg for quadriceps strength, 26 cm for functional reach, 17 steps for stepping test in a standing position, and 14 sec for chair stand test were effective indicators to predict the risk of falling among elderly women living in care facilities. Particularly, the stepping test was most effective in screening the elderly to assess their fall risk.

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VI. References