The Relationship between Quadriceps Strength and Balance to Fall of Elderly Admitted to a Nursing Home

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Abstract. This study was undertaken to determine the relationship between quadriceps strength and balance to falls of institutionalized elderly people. The subjects comprised 25 elderly women aged 75.3 ± 3.4 years. The values of the postural sway in two standing positions, functional reach test, and quadriceps strength were compared between two groups of elderly adults, those with or without a history of fall. Quadriceps strength was measured using isometric contraction of the knee extension. There were no significant differences between the two groups in the postural sway in the two standing positions and the functional reach test. Quadriceps strength in the non-fall group was, however, significantly higher than that in the fall group (1.48 Nm/kg vs. 1.08 Nm/kg, p<0.01). The discriminating criterion for muscle strength between the two groups was 1.28 Nm/kg, with an apparent error rate of 24.8%. These findings suggest that (1) the degree of quadriceps strength may be a useful indicator for the prospect of fall in institutionalized elderly people, and (2) quadriceps strength should be maintained at least more than 1.28 Nm/kg to prevent fall.

Key words: Fall, Elderly, Quadriceps strength, Balance

INTRODUCTION

The fall is one of the most serious and common problems for the elderly who dwell in institutions because of decreasing mobility and increasing mortality. It has been estimated that the annual rate of fall is approximately 30% in community-dwelling elderly who are more than 65 years old1, 2). As for frail elderly people, it is easy to imagine that the rate of fall is much higher. Rubenstein et al. reported that the incidence of fall was about 140 and 165 per 100 patient-years in nursing homes and hospitals3, 4), respectively. Baker et al. indicated that one of five fatal falls among persons aged more than 85 occurs in a nursing home5).

The fall of the elderly is usually regarded as a multi-factorial etiological problem, including intrinsic and extrinsic risk factors. Generally, intrinsic risk factors refer to the characteristics of the individual (e.g. dementia, visual impairment, neurological and musculoskeletal disabilities, and postural hypotension). On the other hand, 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).

Many previous studies have pointed out that muscle weakness and poor balance are well-established intrinsic risk factors for fall in community-dwelling populations6–9). Since frail
elderly people dwelling in institutions tend to have impairments such as muscle weakness and poor balance, they may be associated with a higher incidence of fall in comparison to the community-dwelling elderly.

This study focused on quadriceps strength and balance as intrinsic risk factors of fall, identified which of these factors are associated with an increased risk of fall in institutionalized elderly, and examined the thresholds at which insufficiency increases the risk of fall.

**METHODS**

**Subjects**

The subjects comprised 25 elderly women aged 75.3 ± 3.4 years who dwelled in the same nursing home in Kyoto, Japan. The subjects, therefore, had lived under the same environment and surrounding circumstances. Each subject was able to ambulate either independently or with an assistive device. Those with unstable physical conditions or severe dementia were excluded. Physical dysfunctions such as hemiplegia and osteoarthritis, that might affect mobility in daily activities, were also excluded.

By the presence of an episode of fall in the last six months, the subjects were divided into two groups (non-fall group and fall group). The history of falls was ascertained from incident reports kept at the nursing home. Fall was defined as an event in which a person resulted in coming to rest unintentionally on the ground or another lower level, which was not caused by the result of a major intrinsic event (such as a stroke) or overwhelming hazard.10)

**Balance Test**

The ability of static and dynamic balance were determined by the degree of postural sway in two standing positions and the functional reach test.

Postural sway was measured using the platform center of a foot pressure recorder (G-5500, ANIMA Co.) for 20 seconds in two stances: 1) parallel stance (feet together, side by side), 2) semi-tandem stance (toe of one foot beside the half-way point of the other foot). No assistive devices were allowed and subjects’ eyes were ordered to be kept open during the standing. The measures used in this study were two body sway parameters: the length of the displacement of the center of gravity (LNG: cm), and rectangular area (sway area: cm²).

The ability of dynamic postural control was measured using the functional reach test. The method of functional reach, the measurement of distance that subjects are able to reach forward maintaining a fixed base, has been described by Duncan et al.11, 12. He reported that it had good predictive validity for recurrent falls11) and high intertrial and interrater reliability12). The position of the tip of the first metacarpophalangeal joint was determined, with the shoulder of subject flexed to 90° along a wall. Then subjects were ordered to reach as far forward as possible without moving either foot, thus moving their center of gravity forwards on a fixed base.

**Quadriceps strength**

Quadriceps strength was measured using isometric contraction of the knee extension. Measurements were performed using an isometric dynamometer (GT-100, OG GIKEN Co. Ltd.). The angle between the hip and the knee were 90° in a sitting position, and the strap was placed 10 cm above the ankle. For the maximal isometric strength on the knee extension, the biggest value was adopted from values provided by two repeated measurements after pre-measurement trials using manual resistance.

Each maximal strength isometric contraction was performed bilaterally, and the average values obtained from both legs was calculated. Torque was calculated by the lever arm (distance between the lateral joint line and the point of force application), and expressed as the percentage of body weight (Nm/kg).

**STATISTICAL ANALYSIS**

The differences between the fall group and non-fall group in quadriceps strength, postural sway and functional reach test were calculated using Student’s t-test (two-sample t-test). When this test indicated a difference in a significant level, a discriminatory analysis was performed to calculate the discriminating criteria between the two groups.

**RESULTS**

The fall group consisted of 12 subjects, while the non-fall group consisted of 13. The mean ages of the former and the latter were 75.6 years (SD=3.6)
The mean weights of the fall group and the non-fall group were 56.2 kg (SD=7.3), and 51.8 kg (SD=5.7), respectively (p=0.12). In the fall group, no subject had a fall resulting in serious injuries such as fracture, other head injuries with altered consciousness levels, or obviously decreased ability in daily life.

Table 1 shows the means and standard deviations of postural sway in the two standing positions between the two groups. The two-sample t-test indicated no significant difference between the two groups in both parallel stance and semi-tandem stance in each sway parameter. There was no significant difference in functional reach between the two groups (Table 2).

Quadriceps strength of the fallers was significantly less than that of the non-fallers (1.08 ± 0.30 Nm/kg vs. 1.48 ± 0.21 Nm/kg, Table 2).

The discriminatory analysis showed that the discriminating criterion for quadriceps strength between these two groups was 1.28 Nm/kg with an apparent error rate of 24.8% (Fig. 1).

DISCUSSION

To prevent fall, it is essential to identify and assess risk factors of fall. Though there are a number of community-based studies of risk factors of fall, intrinsic risk factors about fall of the elderly who have adapted themselves to the environment of the institution have not yet been clarified. In this study, the relationships between quadriceps strength and balance to fall of the institutionalized elderly was investigated.

Regarding risk of fall, Asakawa et al.13) indicated that poor knee extension strength of the elderly who dwelled in homes was closely related to fall. Whipple et al.14) reported that the strength of knees and ankles of nursing home residents with a history of fall was significantly decreased in comparison with that of the control subjects without a history of fall. We reveal for the first time in this study that quadriceps strength, in comparison with the balance, of the elderly who had experience of fall in a nursing home was significantly less than that of non-fallers. Because risk factors for falls may differ between healthy and impaired or frail individuals, the selection of the study population may affect which combinations of risk factors are identified. This study examined the association between falls and quadriceps strength in the same subject group, which belonged to the same nursing home and had the same functional status and degree of mobility. It is expected easily that quadriceps weakness would cause gait disorders and increase the risk of falls in

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**Table 1.** Summary of means and standard deviations of postural sway for two standing positions

<table>
<thead>
<tr>
<th></th>
<th>parallel stance</th>
<th>semi-tandem stance</th>
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<tbody>
<tr>
<td></td>
<td>LNG (cm)</td>
<td>sway area (cm²)</td>
</tr>
<tr>
<td>fall group</td>
<td>37.4 ± 6.5</td>
<td>9.9 ± 6.7</td>
</tr>
<tr>
<td>no-fall group</td>
<td>36.6 ± 10.7</td>
<td>15.4 ± 13.7</td>
</tr>
</tbody>
</table>

**Table 2.** Functional reach and quadriceps strength in fall group and no-fall group

<table>
<thead>
<tr>
<th></th>
<th>Functional reach (cm)</th>
<th>Quadriceps strength (Nm/kg)</th>
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<tbody>
<tr>
<td>fall group</td>
<td>25.1 ± 2.9</td>
<td>1.08 ± 0.30**</td>
</tr>
<tr>
<td>no-fall group</td>
<td>26.9 ± 3.4</td>
<td>1.48 ± 0.21</td>
</tr>
</tbody>
</table>

**: significant (t-test: p<0.01) difference between fall group and no-fall group.
frail, nursing home residents, because many studies have demonstrated that quadriceps strength is associated with walking ability\(^{15-17}\). Considering that no subjects had a fall which resulted from serious disease, obviously decreased gait ability or muscle strength, we think the findings of this study suggest that the decrease of strength of quadriceps is a significant and consistent risk factor of fall among institutionalized elderly persons.

Gehlsen et al.\(^6\) reported that static balance determined by the one-foot stance balance test may be a factor contributing to fall in community-dwelling populations. Lord et al.\(^7\) found that increased postural sway increased the risk of fall of the community-dwelling elderly. The result of our present study is in disagreement with the results of Gehlsen\(^6\) and Lord\(^7\), because our study indicated no relationship between the balance function and fall. This difference may be related to differences of the study design and target populations. The subjects in the studies of Gehlsen and Lord consisted of the healthy elderly dwelling independently in the community, while those of ours consisted of the frail elderly dwelling in a nursing home.

The results of this study also suggest that balance, when measured by the postural sway test in two standing positions or the functional reach test, is not a critical factor which staff could use to predict fall of the frail elderly dwelling in institutions. As the laboratory measures of static balance, such as postural sway and center of pressure displacement during quiet stance, do not show a substantial decline with age\(^{18}\), they may be relatively poor indicators of dynamic postural stability during the range of tasks typical of daily life. In contrast, as dynamic measures of balance under stressed or altered sensory or supporting conditions show a more marked decline with age, they could more closely approximate to challenges to balance in daily life, and may be better predictors of the risk of fall than static measures\(^{19, 20}\). Additional research to compare static assessment of balance with dynamic balance and to determine which measure would be relatively useful for the prediction of fall will be required.

It has been reported that the mean score of muscle strength of healthy seniors is about 20\%–40\% lower than that of young adults\(^{21}\). Among chronically ill nursing home residents, muscle strength is considerably less than healthy older persons. Although the precise strength has not been determined, there are several reports that senior adults, even frail senior adults, could improve their muscle strength by suitable exercises\(^{22-25}\). So, the determination of index of minimal effective strength for preventing fall is thought to be necessary and useful for muscle strength training in the elderly. In this study, discriminatory analysis indicated 1.28 Nm/kg of quadriceps strength as the discriminating criterion, with a good error rate, as low as 24.8\%. The results suggest that the utilization of this discriminating criterion, 1.28 Nm/kg of quadriceps strength, would be useful as the minimum level required for the prevention of fall. Namely, the findings about the risk factor revealed by this study are thought to be useful for making a program of prevention of fall, in which intervention should be directed.

Although the efficacy of intervention to prevent fall is limited by the fact that fall has multiple compounding factors which require many different interventions, our findings suggest that interventions targeted to improve quadriceps strength would be the most effective approach for the prevention of fall in the nursing home. The major limitation of the present study was its retrospective design. It remains to be elucidated whether the training of muscle strength will decrease fall.

CONCLUSION

For the prevention of fall of the elderly, quadriceps strength and balance were studied. The results of the present study suggest that quadriceps strength, rather than balance, may be an important intrinsic factor contributing to fall among frail nursing home residents. The data suggest that intervention for prevention of fall should focus on improving quadriceps strength. Furthermore, it is considered that the value of 1.28 Nm/kg of quadriceps strength, as well as a discriminating criteria, may be an useful indicator for screening of elderly who are at a high risk of fall.

REFERENCES

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