Muscle Strength and Muscle Endurance Required for Independent Walking in the Elderly

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Abstract. This study investigated minimal muscle strength on knee extension as well as muscle endurance required for independent walking. Seventy-seven elderly (29 males and 48 females, mean age: 81.3 years) participated in this study. Subjects were divided into two groups (the independent group and the dependent group) based on the Barthel index score. We measured muscle strength and muscle endurance on knee extension. Muscle endurance was evaluated using the ‘sit-to-stand’ test which measured the number of times the subject could rise from a chair within 30 sec. Muscle strength on knee extension was evaluated as a percentage of body weight, calculated from the maximal isometric strength of the knee extensors. The results showed a significant difference in muscle strength on knee extension and the number of repetitions on the ‘sit-to-stand’ test (p<0.01) between the independent group and the dependent group. The discriminating criterion for muscle strength on knee extension between the two groups was 45.5%, while the number of repetitions on the ‘sit-to-stand’ test was 5.6 times. This study suggested that the elderly may need to maintain their muscle strength on knee extension at 45.5% of their body weight and ‘sit-to-stand’ ability at 5.6 times/30 sec to retain their ability to walk independently.

Key words: Muscle strength, Muscle endurance, Walking ability, Elderly.

INTRODUCTION

Completing daily activities successfully becomes a more difficult problem with aging. Especially, retaining independent walking ability is a central problem because it is a basic requirement for activities requiring locomotion and significantly influences the quality of life. Previous studies1) have suggested that muscle strength and muscle endurance are important factors for independence in functional activities including walking. Joel1) reported that the muscle strength of the hamstrings, soleus, and gastrocnemius significantly correlated with the ability to perform activities of daily living (ADL) involving balance and walking.

Several reports have also identified that knee extensor strength was particularly important for walking ability. Aniasson2) found that quadriceps muscle strength was related to walking ability in healthy women. Denise3) reported that slow and fast speed of walking improved with increased knee extensor strength. These studies indicated that knee extensor strength correlated with walking, but the muscle strength and muscle endurance required for independent walking have not yet been clarified. The value of minimal strength requirements for independent walking may be necessary to provide a beneficial effect in muscle strength training.

This study focused on the knee extensor needed,
and the minimum amount of muscle strength and endurance for independent walking.

METHODS

Subjects
Seventy-seven elderly residents of a nursing home participated in this study. Subjects consisted of 29 males and 48 females ranging from 64 to 94 years of age, with a mean age of $81.3 \pm 5.4$ years, and a mean weight of $46.3 \pm 7.5$ kg. Subjects with physical dysfunctions that would affect mobility in ADL such as hemiplegia and osteoarthritis, were excluded.

Evaluation of walking ability
Walking ability was evaluated by the Mobility index, described in the Barthel index. In the Mobility index, independent walking ability was defined as the ability to walk 50 yards without assistance. Then, subjects were divided into two groups, the independent group (n=63) and the dependent group (n=14).

Measurement
Previous studies\(^1\)–\(^3\) have not evaluated muscle endurance, however, this parameter, as well as muscle strength, are important considerations for maintaining ADL function\(^4\). Therefore, we examined muscle function from two perspectives, muscle strength and muscle endurance in knee extension. Muscle endurance was evaluated using the ‘sit-to-stand’ test which counts the number of times that a subject could stand up from a seated position within 30 sec. The subjects were asked to repeatedly rise as fast as they could from a chair with a seat height that was less than knee level from the floor.

Muscle strength on knee extension was evaluated as the percentage of body weight calculated from the maximal isometric strength on knee extension with the knee flexed at $90^\circ$.

Measurements of muscle strength on knee extension were obtained bilaterally using a hand-held dynamometer. The maximal isometric strength on knee extension was determined as the larger of two repeated measurements after pre-measurement trials using manual resistance. Muscle strength on knee extension was calculated as the sum of both sides.

Analysis
The differences between the independent group and the dependent group in muscle strength and muscle endurance on knee extension were examined by a two-sample t-test.

Discriminatory analysis was further added to calculate the discriminating criteria for muscle strength and muscle endurance between the independent and dependent groups.

RESULTS

Table 1 shows a comparison of muscle strength on knee extension and the ‘sit-to-stand’ test score, as muscle endurance, between the independent group and the dependent group. Muscle strength on knee extension in the independent group was $62.0 \pm 19.3\%$, and that in the dependent group was $29.0 \pm 21.6\%$. These results showed that muscle strength on knee extension in the independent group was significantly higher than that in the dependent group (p<0.05). The ‘sit-to-stand’ test score, as muscle endurance, of the independent group was $9.87 \pm 3.9$ times, while that of the dependent group was $1.39 \pm 2.4$ times. There was a significant difference on the ‘sit-to-stand’ test between the independent group and the dependent group (p<0.05).

The discriminating criterion for muscle strength on knee extension between the two groups was $45.5\%$ with an apparent error rate of $20.5\%$, likewise the score on the ‘sit-to-stand’ test was $5.6$ times with an apparent error rate of $13.0\%$ (Table 2).

DISCUSSION

Functional disability in walking leads to such undesirable consequences as fear of falling, loss of confidence, loss of independence and lowered quality of life. Previous studies have suggested that muscle strength on knee extension is related to walking ability\(^2\)–\(^3\). Brown\(^5\) noted a nonsignificant association between walking speed and knee extension, but when muscle strength values for the hip extensors, knee extensors, and plantar flexors were summed together, there was a significant association, explaining $40\%$ of the variability observed in performance. Bassey\(^6\) also found leg extensor power significantly related to walking speed, rising from a chair, and climbing stairs. As suggested by Brown and Bassey, the combined
muscle strength value required for some of these functions affects the smooth forward translation of the center of mass and may be a better indicator of walking speed than muscle strength on knee extension alone. However, the subjects in our studies were either not as healthy as those in their studies or were very frail and had disabilities. Knee extensor strength may be an important factor influencing the ability to walk independently or with assistance. In our previous study, the relationships between mobility and physical fitness measured by muscle strength, muscle endurance, balance, flexibility, grip strength were examined, and the results indicated that muscle strength and muscle endurance on knee extension were closely related to independent mobility in ADL.

Muscle strength training has been reported to be effective for improving ADL ability. Lester showed that a group participating in a strength-building exercise program for 12 weeks showed improved walking ability with increasing quadriceps muscle strength and endurance. Fiatarone provided evidence that improvements in quadriceps femoris and hip extensor muscle strength resulted in improved walking and stair climbing ability. Thus, recent reports have stressed the effect of muscle strength training for maintaining ability in ADL. Although muscle strength training is now being actively encouraged in the elderly, the fact is that the goals in muscle strength training are not specific. Establishing minimal strength requirements for independent walking will be a useful index for strength training in the elderly. In this study, discriminatory analysis showed 45.5% of muscle strength as the discriminating criterion, with an error rate of 13.0%. This discriminating criterion is a useful indicator for the minimal level needed to maintain independent walking ability because the error rate was low for a single factor value.

Previous studies have failed to demonstrate a relationship with other muscle functions, such as muscle endurance, and ADL ability. In our test, both muscle strength and muscle endurance on knee extension were measured. The results indicated that muscle endurance on knee extension in the independent group was significantly higher than the dependent group. Furthermore, discriminatory analysis showed a good error rate, as low as 20.5% for muscle endurance. These facts indicated that muscle endurance, as well as muscle strength on knee extension, was closely related with walking ability. As a result, it was regarded that 5.6 times was the discriminating criterion for the ‘sit-to-stand’ test score and was a useful indicator of the lowest level needed to maintain independent walking ability.

We conclude that muscle strength and endurance in knee extension are related to independent walking, and that 45.5% muscle strength and a score of 5.6 times on the ‘sit-to-stand’ test are needed for independent walking. Future studies may consider associations between independent walking and various other factors including other muscle functions, and quantitatively evaluate the variables needed to maintain functional independence.

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<tr>
<th>Table 1. Comparison of muscle strength and ‘sit-to-stand’ test score between the independent group and dependent group</th>
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<td>muscle strength (% of body weight)</td>
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<td>‘sit-to-stand’ test (repetitions)</td>
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Values represent means ± SD

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<th>Table 2. Results of discriminatory analysis</th>
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REFERENCES


