1. Introduction

Since April 2000, when the Long Term Care Insurance System was initiated, the number of people in Japan who were certified as requiring long-term care increased by 88% over five years, from 2,180,000 to 4,110,000 by the end of April 2005. In particular, the number of people requiring some minimum kind of long-term care or support (termed ‘Support Required’ in the former care category, and ‘Care Level 1’ in the revised category) increased by 138% to occupy half of those certified as requiring long-term care (Report on Long-term Care Insurance Service Condition). The underlying health problems of individuals requiring this kind of minimum long-term care or support varies in each case, but the condition of "disuse syndrome", in which vital functions gradually weaken, is frequently seen or the risk of this syndrome is great in many cases. It has been suggested that early preventive treatment and rehabilitation are extremely important for the maintenance and improvement of vital functions. As a result the revision of the Long-term Care Insurance Law in 2006 announced a conversion to a prevention-oriented system. Various programs have been provided to promote preventive treatment. These include locomotory function improvement programs such as muscle strength improvement exercises and fall prevention practice. Their purpose is to improve individuals’ psychosomatic condition and to counter the aggravation of people who require some long-term care (those people, in Support Required and Care Level 1 in the former care category or Support Required 1 and 2, and Care Level 1 in the revised category).

According to the Law for Long Term Care Insurance, "Care Required" means "a condition in which continuing full-time nursing care is apparently required for basic activities of daily living including bathing, excretion and dining because of physical or mental disorder during a certain period determined by the ordinance of Ministry of Health, Labor and Welfare, and which corresponds to the category of Care Required levels established by the ministerial authority."
ordinance" (Article 7, Section 1). The Ministry of Health, Labor and Welfare states that "Support Required" means a condition which requires certain support for instrumental activities of daily living in order to prevent from becoming a care requiring condition and to control the current condition, even though a care receiver can perform the basic activities of daily living by themselves" (Elderly Care Study Group Report, 2003). The "basic activities of daily living (ADL)" quoted here include such activities as dining, bathing and excretion, but "instrumental activities of daily living (IADL)" indicate activities in which applied movement of ADL is required, such as telephoning, shopping help with meals, domestic chores, washing, transport, going out, controlling medication and controlling money (Long-term care / health and welfare dictionary). That is, the standard for long-term care requirement certification is "a need for ADL support" and the condition "requiring support for IADL but not for assistance for ADL" is the "Support Required" condition. Depending on the amount of assistance required for ADL, long-term care requirement levels are determined.

Various measurement indexes of ADL as the criterion of care required condition have been invented to assess performance ability. It has also been frequently suggested that mobility (including walking speed and one leg standing with eyes open endurance), and muscle strength and thickness should be included in the ADL indexes (Bassey et al., 1992; Ehashi, 1994; Potter et al., 1995; Rantanen et al., 2002). As mentioned above, the "care required condition" is "the condition which requires ADL assistance". A definition that includes conditions in enforcing the law where the greater the need for ADL assistance, the higher the level of care becomes (that is, the lower the ability in performing ADL, the higher the level of care becomes) predicts the possibility that "the higher the level of care required, the lower the numeric value of mobility and muscle strength/thickness becomes".

In order to certify the level of long-term care required by an individual, a certification examiner judges primarily whether each item regarding ADL and IADL can or cannot be performed. The willingness of the individual plays a part in whether each ADL can be performed, and the family environment is also referred to in the certification examination. Thus, the result does not solely reflect a person’s physical condition. Muscle strength and functions are not measured directly; however, many long-term care prevention programs adopt muscle strength improvement exercise to improve muscle function and muscle strength. As "muscle strength cannot simply describe life" (Nagasawa, 2004), mobility and muscle strength and thickness are not the only determinant in the long-term care requirement certification of frail elderly people. Nevertheless, the relationship between the condition of long-term care required and mobility and muscle strength and thickness has not been investigated yet as far as we know. Moreover, the relationship between the performance ability of IADL (IADL index) and mobility and muscle strength and thickness has not been elucidated either.

This study, therefore, examines the relationship between muscle thickness, strength and mobility and the IADL index as well as care levels, in subjects with long-term care requirement certification and frail elderly people without such certification.

2. Methods

2.1. Subjects

The subjects of this study were 20 frail elderly people who participated in the long-term care prevention programs were held by a community and 68 users of two day-service centers for persons requiring long-term care. People with dementia were excluded from the study. This study was approved by the Ethical Committee of Faculty of Sport Sciences, Waseda University. The subjects were fully informed of the procedures to be used as well as the purpose of the study and signed on the given consent form.

The subjects were divided into three groups according to the level of long-term care requirement certification. As this study was conducted before the Long Term Care Insurance System was revised in April 2006, the level of care required in the original system was adopted. The three groups were: "independent" subjects who do not receive long-term care requirement certification; "light care receivers" (light hereafter) who are in Support Required and Care Level 1; and, "heavy care receivers" (heavy hereafter) who are certified as at Care Levels 2, 3, 4, and 5. Profiles of subjects are shown in Table 1.

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Ota, A., et al.
2.2. Measurements

2.2.1. Knee extensor thickness

A real time B-mode ultrasound apparatus (SSD-1000, Aloka) was used to obtain cross sectional images at thigh after Fukunaga and Kanehisa (1990). The measurement site was mainly on the rectus femoris muscle including the anterior thigh and from the femur greater trochanter to 50% of the femoral length. Although the right leg was measured in general, those subjects whose left legs had been measured in measuring knee extensor torque were also measured on the left leg.

2.2.2. Knee extensor torque

A knee joint torquemeter (VINE) is used in measuring the muscle function of frail elderly people in long-term care prevention programs in Tokyo. Since this torquemeter could not be placed in day-service centers, hand-held dynamometers (Isoforce GT-610; OG Giken, Powertrack II MMTCommander; Japan Medix) were used to measure muscle strength with the torque calculated based on the length from the knee joint to the attachment. The Isoforce GT-610 consists of a sensor and belt and measures muscle strength by detecting tension on the belt. In contrast the Powertrack II is a hand-held device and measures strain through a sensor. All the attachments of measurement equipment were placed 5 cm above the external malleolus while the knee joint angle was maintained at 90°. Subjects were instructed to grip the measuring stand with both hands and to keep their body trunk in a vertical position. During measurement, a knee extension exercise of about 3 seconds was conducted twice at maximal effort and the larger score was recorded. While measurement was conducted with the right leg in general, the left leg was substituted for those who could not use their right leg in measurement because of some kind of disorder or numbness.

Since previous studies (Arai et al., 2006; Hirasawa et al., 2005; Tatsu et al., 2003) assessed results by converting measured figures to joint torque values, the validity of each measurement of this study is considered to have been verified.

2.3. Mobility

One leg standing with open eyes endurance and 5m walking speed (ordinary speed) tests were conducted following Suzuki and Ohbuchi’s (2005) long-term care prevention manual. Subjects were instructed by the examiner to put down both hands freely and to keep standing on one leg as long as possible during the one leg standing with open eyes endurance test. In addition, they were told not to touch their supporting leg with the other leg. Each subject was free to decide which leg to raise and how high above the floor to raise it. The maximum measuring time was determined to be 60 seconds and a second test was conducted when the first endurance time was less than 60 seconds. The larger score was recorded. In the 5m walking speed test, each subject was asked to walk along an 11m walking course which included a distance of 3m before and after the measured 5m. Subjects were instructed to walk "at their usual speed".

Since there were several subjects who could not perform these tests, the rate of participants who accomplished the test was calculated by the level of long-term care requirement certification. In the one leg standing with open eyes endurance test, if a subject could step without holding onto something,

<table>
<thead>
<tr>
<th>levels of dependence of certified care</th>
<th>independent</th>
<th>light</th>
<th>heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>number (male/female)</td>
<td>15(8/7)</td>
<td>46(18/28)</td>
<td>27(9/18)</td>
</tr>
<tr>
<td>age</td>
<td>73.3 ± 5.4</td>
<td>79.6 ± 7.8*</td>
<td>77.0 ± 8.9</td>
</tr>
<tr>
<td>height (cm)</td>
<td>155.8 ± 9.8</td>
<td>150.0 ± 10.7</td>
<td>147.3 ± 8.4*</td>
</tr>
<tr>
<td>weight (kg)</td>
<td>57.7 ± 14.3</td>
<td>51.1 ± 10.6</td>
<td>49.5 ± 11.4</td>
</tr>
</tbody>
</table>

*: p < 0.05 vs. independent
Table 2  Results of muscle function, mobility tests and IADL according to their levels of dependence of certified care

<table>
<thead>
<tr>
<th></th>
<th>independent</th>
<th>light</th>
<th>heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>thigh muscle thickness</td>
<td>mm</td>
<td>34.7 ± 6.6</td>
<td>29.9 ± 5.4</td>
</tr>
<tr>
<td>knee extensor strength</td>
<td>Nm/kg</td>
<td>1.14 ± 0.62</td>
<td>0.88 ± 0.33</td>
</tr>
<tr>
<td>accomplishment of walking test</td>
<td>%</td>
<td>100</td>
<td>93</td>
</tr>
<tr>
<td>accomplishment of one leg standing</td>
<td>%</td>
<td>100</td>
<td>76</td>
</tr>
<tr>
<td>TIMG-Index of Competence</td>
<td>total score</td>
<td>1.4 ± 1.6</td>
<td>4.2 ± 3.1**</td>
</tr>
</tbody>
</table>

Values are means ± SD. **; p < 0.01 vs. independent, ††; p < 0.01 vs. light

he/she was ascribed as "accomplished". In 5m walking test, if a subject could walk the 11m walking course on his/her own, he/she was ascribed as "accomplished".

2.4. IADL performance (IADL index)

The Tokyo Metropolitan Institute of Gerontology (TMIG) index of competence (Koyano, et al., 1987) was used as the IADL index. This index was developed in order to assess the higher ADL functions of elderly people including the standard of "social role" raised by Lawton (1977). It consists of 13 questions based on the primary factors of "instrumental independence", "intellectual activeness" and "social role". The total points scored were used for the assessment in this study.

2.5. Statistical analysis

2.5.1. Relationship of care level with IADL index, mobility and muscle strength and mass  
Covariance analysis was used to examine the relationship between the long-term care requirement certification and the IADL index, knee extensor strength and anterior thigh muscle thickness. In order to eliminate the influence of gender and age by group, the condition of long-term care requirement certification was specified as an autonomous variable, and age and gender as covariates. An χ² test was performed to compare the rate of measurable subjects relating to the condition of long-term care requirement certification and the 5m walking and one leg standing tests.

2.5.2 Relationship of IADL index with mobility and muscle strength and mass

Subjects were divided almost evenly into three groups (high, middle and low) according to the IADL index level and the analysis was conducted on the relationship of the IADL index with mobility and muscle strength and mass. The Kruskal-Wallis rank sum test was used to examine the relationship between IADL level and mobility, and covariance analysis was used for examining the relationship between IADL level and muscle strength and mass with gender and age as covariates.

2.5.3. Relationship between mobility and muscle strength and mass

Subjects were grouped into "accomplishment" and "failure" for both the 5m walking and one leg standing tests. Covariance analysis was performed for each test with gender and age as covariates and muscle strength or mass as a dependent variable.

3. Results

3.1. Relationship of care level with muscle strength and mass, mobility and ADL

Table 2 shows the results of muscle function, TIMG-index of competence and the rate of subjects who accomplished the 5m walking and one leg standing tests classified by their levels of dependence in certified care. Significant differences by care level were not observed in anterior thigh muscle thickness or knee extension strength torque per weight. The number of subjects who performed the one leg standing with open eyes endurance test and 5m walking speed test were 14 for the independent level, 42 for the light level and 26 for the heavy level.
One hundred percent of independent level (14). 76% of light level (32) and 23% of heavy level (5) were accomplished performers for the one leg standing with open eyes test, while 100% of independent level (14), 93% of light level (39) and 38% of heavy level (7) were accomplished performers at the 5m walking test. The rate of accomplishment decreases as the care level becomes higher, both at the one leg standing with open eyes test and the 5m walking test, and a significant difference was observed between the independent level and the heavy level. The average total points of the TIMG-index of competence increases as the care level increases, and a significant difference was observed between the independent level and light/heavy levels and between light and heavy levels. This means that ADL competence decreases as the care level rises.

### 3.2. Relationship of IADL index with mobility and muscle thickness and strength

Table 3 shows the rate of accomplishment in the mobility tests and the results of muscle function classified by the level of the TIMG IADL index. Significant differences were observed in mobility both in the one leg standing test and the 5m walking test (p<0.01). IADL levels did not show any significant difference in the relationship with anterior thigh muscle thickness and knee extension strength.

### 3.3. Relationship between mobility and muscle thickness and strength

The accomplishment group showed significantly higher values both at 5m walking and one leg standing with open eyes (5m walking; accomplishment 0.95 ± 0.44Nm/kg, failure 0.65 ± 0.31Nm/kg, p<0.05, one leg standing; accomplishment 0.98 ± 0.44Nm/kg, failure 0.71 ± 0.34Nm/kg, p<0.05). Again, no differences were observed in anterior thigh muscle thickness by group (5m walking; accomplishment 31.1 ± 6.1mm, failure 30.1 ± 7.7mm, one leg standing; accomplishment 30.6 ± 6.1mm, failure 31.3 ± 7.1mm). An analysis of care receivers only shows similar results in which muscle strength values are significantly higher in the accomplishment group and no difference between groups was observed in anterior thigh muscle thickness.

### 4. Considerations

People receive long-term care service through the Long Term Care Insurance System in order to live as independent a life as possible, especially when they need some support or care because of a health problem due to physical and mental changes caused by aging. When receiving care, the certification of care level is conducted to determine the care requirement level based on the time length (standard time for care requirement certification) taken for four care areas: "direct life support", "activity relating to difficult behavior", "activity relating to functional training", and "medical-related activity". The time is assessed mainly through items relating to ADL such as dining, bathing and excretion and those relating to IADL such as telephoning, shopping, meal support, domestic chores, washing, transport, going out, medication control and money control. Some items relating to medical care and cognition are also included.

Many reports claim that the performance ability of ADL involves muscle strength and mobility. It is also reported that walking speed (Potter, et al., 1995) and muscle strength (Rantanen, et al., 2002) are useful as predictive factors of the ADL index for elderly people. One study of physically healthy elderly people staying at home reported that a significant correlation was observed between anterior thigh muscle thickness and ADL competence in...
elderly people (Ebashi, et al., 1994). A study on the relationship between mobility and muscle strength observed a relationship between one leg standing with open eyes endurance and knee extensor strength (Kasahara, et al., 2001), and a study on care service center residents who can walk on their own reported on the relationship between knee extensor strength, walking speed, rising from a chair speed, and knee joint extension speed (Bassey, et al., 1992).

Based on these previous studies it is natural to expect some relationship between care level and mobility and muscle strength and mass. However, this study of the relationship of care level with walking, one leg standing, knee extensor strength and anterior thigh muscle thickness showed no significant differences in the relationship between care level and knee extensor strength and anterior thigh muscle thickness, even though significant differences were observed in the rate of accomplishment of walking and one leg standing tests according to care level. Needless to say, it is possible that Type II errors might have occurred. Moreover, the fact that no significant difference was observed may not straightforwardly mean the measured items are irrelevant. The results of this study, however, could suggest at least the possibility that there are certified care receivers who have muscle strength and mass which is almost identical to independent people.

Subjects grouped as "independent" were those who attend exercise classes for frail elderly people in their residential region. Their muscle strength and mass are less compared to healthy elderly people. Putting it another way, the results which showed that the muscle strength and mass of elderly people with long-term care requirement certification did not necessarily correspond to the care level suggest that a decrease in muscle strength and mass, that is the "ability" of muscle itself, does not always lead to the condition of care required. This indicates that some certified care receivers have muscle strength equivalent to independent elderly people and that it is possible for such subjects to improve their complex movements including sitting, standing and walking. This can be done through encouraging the subjects to do so by themselves and by practicing exercises relating to daily living activity. While muscle training has gathered attention recently, the results of this study indicate that an increase in muscle strength and mass should not be specifically noted as the outcome indicator of muscle training.

There are two main limitations of this study. Since the subjects of this study were elderly people with less overall physical fitness, there may be great differences between individuals and Type II errors may occur. A further problem is that the male-female ratio and age levels were different between the independent group and care required groups. This cannot be resolved through analysis of covariance using linear models, granted that gender and age were adjusted as covariates. Thus, it is not possible to conclude that there is no clear relation between care level and muscle strength and thickness and a large scale follow-up investigation needs to be conducted to elucidate this. Given the social circumstances where long-term care prevention projects and their assessment are urgently needed, it is recommended that motivation levels of subjects and improvements to daily living activity should be focused on as well as muscle strength improvement in long-term care prevention programs.

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References


Strength and Thickness of Knee Extensor Muscles in Frail Elderly

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