Reduction in Fall Risk and Medical Cost with Foot Care in the Elderly

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Abstract
Objectives: Foot problems are common in the elderly and are associated with impaired lower limb muscle strength, reduced balance function, and foot pain. We investigated the effect of foot care on these parameters as well as on medical costs in 32 community-dwelling elders (mean age 75.3 ± 6.1 years). They were divided into two groups based on pre-intervention fall risk assessed by lower limb muscle strength. In this study, we examined the impact of foot care intervention on medical costs by conducting an analysis on the medical costs of the subjects who had been compensated by the National Health Insurance or by the medical care system for those aged over 75 years.

Measurements: Lower limb muscle strength was evaluated by measuring toe-gap force and knee-gap force. Balance capability was evaluated by the trajectory of the length and area of center of pressure (COP) and pressure ratio of toe contact with the ground. Medical costs were compared before and after intervention.

Results: Significant increases in toe-gap force and knee-gap force were observed after foot care intervention. Post-intervention toe-gap force and knee-gap force were significantly lower in the foot pain group than in the foot pain-free group. The toe-gap force and knee-gap force in both groups improved significantly after foot care intervention. The subjects who had pain in their feet were significantly more likely to belong to the higher fall risk group. There was a reduction in medical costs for the group of the over-75 group.

Conclusion: In community-dwelling elderly, foot care improves lower limb muscle strength and balance, which are associated with falls, and reduces medical costs.

Keywords: foot care, fall risk, lower limb muscle strength, balance, foot pain.

1. Introduction

Studies have shown that regardless of the presence of diabetes, up to 80% of community-dwelling elderly have foot problems including the presence of a corn, bunion, hallux valgus, plantar hyperkeratosis, lesser digital deformity, and ingrown toenail [1–3]. These problems are associated with impairment of both mobility and the ability to perform general housekeeping abilities [4–6]. In addition, retrospective studies reported that the fall risk was four times higher in elderly with foot problems compared to those without [7, 8].

Decreases in balancing function, walking ability, and lower-limb muscle strength have been reported to be associated with falls [9–12]. Because foot problems negatively affect these three factors in the elderly and increase the likelihood of falls, foot care may be an important part of fall prevention. However, this relationship has not yet been evaluated in community-dwelling elderly.

In addition, the economic impact of falls and fractures in the elderly has been analyzed from the standpoint of medical costs [13–15]. However, there are no reports on the effect of foot care on medical costs of healthy elderly.

Therefore, this study focused on the effect of 10 months of foot care on changes in biomechanical functions related to fall risks in a group of community-dwelling, relatively active elderly subjects. In this study, we also analyzed changes in medical expenses for these subjects.

2. Methods

2.1 Subjects

Thirty-two community-dwelling elderly aged 65 years or older were recruited via advertisements to participate in this study. These elderly people participated in a foot-care program. Of the 32 subjects, 14 had hypertension, 4 had diabetes (2 with multiple hypertension-related diseases), 7 had osteoporosis (3 with multiple hypertension-related diseases and 1 with multiple diabetes-related diseases), and 5 had knee osteoarthritis. Twenty-seven subjects were on some types of prescription medication; 16 had pain in their feet or toes or both; and 9 had experienced a fall during the past year. Foot and toenail pain was surveyed using a questionnaire.

Subjects whose medical costs could be obtained for the year...
and the year before the foot care intervention were included in the medical cost analysis. Of these, the medical costs of 26 subjects were analyzed. The medical costs of 10 subjects aged between 66 and 74 years were covered by national health insurance. Medical costs of 16 subjects aged between 76 and 86 years were covered by the medical insurance system for the elderly aged 75 or over. Table 1 shows the participants’ characteristics as well as a breakdown of sources of compensation. Data are expressed as mean ± standard deviation unless otherwise noted.

2.2 Measurement of biomechanical function

Devices were used to measure lower limb muscle strength [16–19]. The apparatuses shown in Fig. 1 to 3 were developed for the purpose of this study. In this study, a toe-gap force measurement device (Fig. 1) was used to evaluate muscle strength under the knee, including total plantar area [16]. The clipping toe-gap force was measured between the great toe and the digitus secundus. The toe-gap force is exerted through muscles of the lower limb, which are known to contribute to prevent falls. The knee-gap force measurement device (Fig. 2) was used as an indicator of the strength of hip adductor and abductor muscles [17].

High correlation has been found between muscle strength determined by these devices and 10-meter walking speed, as well as 10-meter obstacle walking speed [16]. These were used to estimate fall risk using static measurements.

Previous studies revealed that elderly at high risk of falling, as determined by fall risk indices, had left foot toe-gap force below 2.4 kgf or knee-gap force below 18 kgf (odds ratio, 9.1) [17, 18]. We therefore used these indices to classify subjects’ fall risk using the evaluation results before intervention.

Both measurements were performed while the subject remained in a sitting position. During measurement, ankle and knee joints were set to roughly 90 degrees, with the heels remaining on the ground so as not to affect the results.

The shoe-type stabilometer (Fig. 3) used to assess balance was available in multiple sizes to accommodate the foot sizes of the subjects, thereby ensuring the reliability of measurement results. Seven pressure sensors on the insoles of each pair of stabilometer transmitted wireless Bluetooth® data at a sampling frequency of 100 Hz [20, 21]. The subject maintained a quiet standing posture for 45 seconds with eyes open and feet apart. Measurements were taken 12 cm from the toes, with the heels 8 cm apart. After measurement, the center of pressure (COP) was calculated from the pressure values of the 14 sensors.

Pressure ratio of toe contact with the ground as well as total trajectory length and sway area of COP were also calculated. The pressure ratio of toe contact with the ground was calculated as the total pressure determined from two big-toe sensors, divided by the total pressure measured from 14 sensors. The pressure ratio of toe contact with the ground is evaluated the contribution of the toes during standing posture [21]. If the toes are not in contact with the ground, the pressure ratio of the toe contact with the ground is zero. Plantar tactile sensation and strength of toe plantar/flexor muscles are independent predictors of balance function [22]. Toe plantar flexor weakness impairs the grasping function of the toes when performing weight-bearing activities, resulting in impaired balance and increased fall risk [23, 24]. Therefore, reduced toe flexor strength and the presence of toe deformities increase the fall risk in the elderly [25].

The function of the toes directly affects postural stability. We used total trajectory length and area as indices of postural stability. The higher the pressure ratio, the greater is the contribution of the toes to postural control, because the toes fulfill the role as the motor unit of postural control. In addition, toe-gap force also re-

### Table 1

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<th>Characteristic of intervention group</th>
<th>medical cost analysis group under 75 years old</th>
<th>medical cost analysis group 75 years and over</th>
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<tr>
<td>number of subjects</td>
<td>32</td>
<td>10</td>
</tr>
<tr>
<td>age [years]</td>
<td>75.3 ± 6.1</td>
<td>70.2 ± 2.9</td>
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<tr>
<td>body weight [kg]</td>
<td>52.1 ± 9.8</td>
<td>52.2 ± 12.5</td>
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Fig. 1 Toe-gap measurement device.  
Fig. 2 Knee-gap force measurement device.  
Fig. 3 Shoe-type stabilometer.
fects the toe plantar flexor muscle strength.

The total trajectory length represents the length of the trajectory of the displacement of COP. The sway area of COP is used to estimate postural performance. The total trajectory length and the sway area of COP were chosen because they have previously been shown to be useful in assessing postural stability [24].

Subjects were interviewed to obtain medical history including whether they had ever experienced foot pain.

### 2.3 Foot care intervention

The foot care intervention was administered by nurses with specialized knowledge and skills in foot care, such as cutting problematic toenails and foot care for the elderly.

The foot care intervention program consisted of care of ingrown toenails, thickened and deformed toenail surfaces, and calluses on the heels and soles of the feet. The foot care nurses also provided instruction on routine foot and toenail care. The care provided to subjects with ingrown and thickened toenails allowed recovery from these foot issues in approximately 6 months. Subjects received foot care once per month. Measurements were carried out before and at the end of 10 months’ foot care intervention.

The Human Studies Ethics Committee at the Tokyo Healthcare University approved this study, and informed consent was obtained from all subjects before participation. All participants provided written informed consent.

### 2.4 Analysis of foot-care intervention effects

Statistics software (PASW Statistics for Windows, Version 18.0, SPSS Inc., USA) was used for our analysis. The t-test was used to determine differences between groups categorized by age, fall risk, and presence or absence of foot pain. A correlation t-test was used to evaluate changes before and after intervention. Pearson’s χ² test was used to classify fall risk based on the presence or absence of foot pain.

### 3. Results

#### 3.1 Patient characteristics and results of foot care intervention

Table 2 shows the results of measurements before and after intervention. Data are expressed as mean ± standard deviation. After intervention, significant improvements were seen in lower limb muscle strength (toe-gap force and knee-gap force were approximately 1.4 times greater after intervention compared to before). Pressure ratio of toe contact with the ground doubled, and trajectory area of COP was reduced by 50%.

#### 3.2 Effect of foot care intervention on fall risk index

Figure 4 shows the results of intervention represented by lower limb muscle strength, as assessed by (a) toe-gap force and (b) knee-gap force, between higher fall risk and lower fall risk groups.

Before intervention, 9 subjects were classified by lower limb muscle strength in the lower fall risk group and 23 in the higher fall risk group. After foot care intervention, 13 subjects in the higher fall risk group shifted to the lower fall risk group. No sub-

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<th>Table 2 Pre- and post-intervention measurement results.</th>
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<tr>
<td>toe gap force (right) [kgf]</td>
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<td>toe gap force (left) [kgf]</td>
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<tr>
<td>knee gap force [kgf]</td>
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<tr>
<td>pressure ratio of the toe contact with the ground [%]</td>
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<tr>
<td>sway area [cm²]</td>
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<tr>
<td>total path length [mm]</td>
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</table>

Fig. 4 Comparison of rates of intervention-related improvement in lower-limb muscle strength, as assessed by (a) toe-gap force and (b) knee-gap force, between higher fall risk and lower fall risk groups.
reduced in 10. In the year before intervention, 5 subjects in the over 75 group had medical costs over $3,508.8, including 4 with costs of $6,940.2. This was reduced to $3,493.2 through intervention.

In the higher fall risk group, medical cost decreased by $496.6 after a year of intervention. In addition, 13 subjects aged over 75 accounted for 65% of the higher fall risk group. The reduction of medical cost in the higher fall risk group was greater than that in the lower fall risk group.

4. Discussion

4.1 Effect of foot care intervention on lower limb muscle strength

In this study, lower limb muscle strength improved after intervention in all groups, whether classified by fall risk or by presence or absence of foot pain. In particular, subjects who were considered to be at higher risk of falls because of decline in lower limb muscle strength showed increases of 1.6 and 1.9 times in toe-gap force and knee-gap force, respectively, as a result of foot care. Moreover, 57% of subjects in the higher fall risk group shifted to the lower fall risk group as a result of 10 months of foot care intervention.

We found that 65% of the subjects in the higher fall risk group had foot pain. Implementation of foot care in these subjects was effective in improving foot functions related to lower limb muscle strength, leading to reduced fall risk.

4.2 Effect of foot-care on balance function

The role of the forefoot in balance and as the base of support, as well as its contribution to postural control in the anteroposterior plane have been described [25]. In the presented study, we found that implementation of foot care doubled the pressure ratio of the toe contact with the ground. In particular, the pressure ratio improved significantly in subjects with higher fall risk and in those with foot pain. As a result, there was reduction in the trajectory area of COP when remaining in the quiet standing position. We believe this can be attributed to the improved function of the toes and the forefoot, which resulted in a greater ability to control posture.

Implementation of foot care in healthy elderly people improved lower limb muscle strength and balance function. The in-
timate involvement of lower limb muscle strength and balance function with fall risks [9–11] suggests that foot care has the potential to lower such risks.

4.3 Effect of foot care on medical costs
In the present study, 10 months of foot care reduced medical costs by an average of $448.6, or 20.1%. This study revealed that mean medical costs in the over 75 group were $1474.7 higher in the year preceding foot care intervention, and $455.4 higher during the foot-care intervention, when compared to the medical costs in the under 75 group.

In the over 75 group, which is the group that raises medical costs [26], we found that foot-care resulted in a reduction of about $840.6 after a year of foot care intervention. Foot-care intervention reduced medical costs by about $496.6 in the higher fall risk group in the same period. Therefore, foot care intervention was effective in controlling expensive medical cost in those aged 75 years and over.

This study included subjects with osteoarthritis and foot pain. To separately analyze the reasons for the reduction of medical costs in subjects with these conditions, it would be necessary to carry out a detailed health insurance claims data analysis, a task we plan to carry out in a future study.

In the present study, reduction in foot pain improved lower limb muscle strength and balance function, suggesting that foot care can improve conditions related to orthopedic ailments.

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References