# Evaluation of Falling Risk by Toe-gap Force on Aged

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**Abstract: A simple method is desired that can evaluate the physical functions of the aged against fall. This paper proposes a toe-gap force measurement as an evaluation of the lower limb muscular power for this purpose. The effectiveness of the method is examined from the viewpoints of anatomy, comparison with the conventional measurement method and practically useful method. In the proposed method, the clipping toe-gap force is measured between the great toe and the digitus secundus. The toe-gap force in this situation, is generated by the collaboration of the flexor tensor muscles of the lower limb, which are supposed to have roles in the effort against falling. The measurement device has a structure similar to the grip dynamometer, and the toe-gap force is displayed by a mechanical structure. As to the physical strength against falling, 153 subjects were tested and results were compared to the indication of the proposed device. It is seen that the measured toe-gap force is closely related to the physical strength of the lower limb examined the general examination. It is thus concluded that, the proposed method can be a practically useful method for evaluating quantitatively the lower limb muscular power of the aged against fall.**

## Introduction

Many countries are gradually foming the aging society. For example, the ratio of aging population is 20.4% in Japan, 20.0% in Italy, 18.8% in Deutchland. Falling is one of the most common and most serious problems associated with aged. Falling causes the hip fracture and the bed-bound, and increases national medical expenses for the aged. About 1% of falls cause hip fracture, and about 5% result in any type of fracture[1]. In addition to the injuries, psychosocial problems such as fear of falling lead to social withdrawal, inactivity, and immobility[2].

In Japan, the 3.5 million aged people whose falling risk is high by physical weakness is estimated. Decade from now with the graying of the baby-boom generation, it is indicated that fall-related problems such as hip fractures will quadruple over the next 40 years[2]. It is easy to assume that the fall-related problems will heavily task the health care systems, as the medical expenses for the elderly, unless effective approaches to prevent falls and develop new method and device about prevention falls.

The some of falling factors are the decline of lower limb muscular power and ability of postural control[3]. Especially, it is important that the lower limb muscular power have directly related to the postural stability.

For example, the cybex , or the ergomator is a assessment procedure of lower limb muscular power at the rihabilitation hospital. These are so big and expensive that healthy aged people can not use it. There is no adequate method, by which we can assess the lower limb muscular power. So a simple and quantitative method is desiderated widely to evaluate the lower limb muscular power of the aged. Then the toe-gap force measurement device was developed to assess the lower limb muscular power for aged people.

The purpose of this study was to assess the relationship between toe-gap force and conventional measurement of physical function in health young old and old old. We also examined to effectiveness of the method by the usual training for prevention of falling was tried.

## Materials and Methods

### Toe-gap force measurement device

Fig.1,2 shows the measuring device for toe-gap force. In the proposed method, the clipping toe-gap force is measured between the great-toe and the digitus

secundus. This device has a structure similar to the grip dynamometer, and the toe-gap force is displayed by a mechanical structure.

Fig.3 shows the muscles have effects in generating the clipping force. Muscles of directly related to the toe-gap force are the transverse head of adductor hallucis and the plantar interossei[4]. The movements of the toe are generated by collaborative actions of flexor-tensor muscles, such as the flexor hallucis brevis, the flexor digitorum longus, the floxor digitorum brevis, etc.. These muscles compose the lowest part of the feet. Thus, the measurement of the toe-gap force is the general assessment of muscular power in the lower limb.

Analogous to the fact that the grip of hands is generated by the collaborative actions of the distal muscles of upper extremity[5], it is considered that the toe-gap force reflects the lower limb muscular power.

These muscles play the important roles in fixing the great-toe as well as in walking, in final term of stance phase[6]. Degradation of these flexor muscles force and the tibialis anterior will produce stumbling, which is the main cause of falls. These muscles also enhance the function of all constituents of the plantar arch. The arch of foot works as a shock absorber and functions of the postural control. The toe-gap force measurement can be used to evaluate these flexor muscles of the lower limb.

Figure 1 The device of toe-gap force measurement

Figure 2 Example of how the device is used

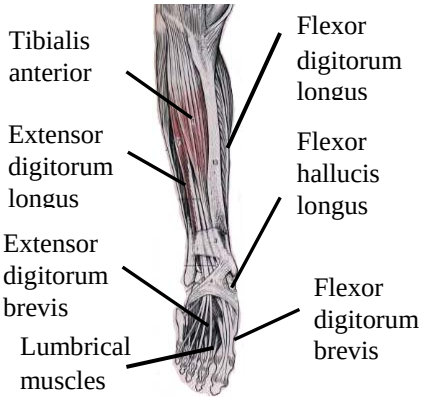


Figure 3 Anatomy view of lower limb

**Experiment 1:**

The subjects were 153 healthy volunteers in this experiment. For the assessment of lower limb muscular power, the subjects were divided into two age group as young old (age range 65-74 years, mean 71.2 ± 2.0 years, 9 males and 20 females) and old old (age range 75-95 years, mean 81.8±5.0 years, 13 males and 111 females).

The toe-gap force was compared with the basic physical function, the lower limb muscular power and the upper limb muscular power, because there are many reports such as a risk of fall which have relationship between the 10 m walking time, the maximum grip strength and the experience of fall[3,7,8].

All subjects were tested the toe-gap force and conventional measurement of physical function as age, hight, weight, body mass index (BMI), 10 m walking time and maximum grip strength. Relation between the toe-gap force and the falling experience for one year were examined to evaluate falling risk.

The results of toe-gap force and conventional measurement were made using Wilcoxon sign-ranks test. The comparisons of toe-gap force between faller and non-faller were made using One-factor ANOVA, and decided as significant, with risk of 5 %. The results between the toe-gap force and the experience of fall was analyzed by Student's T-test.

**Experiment 2:**

It is examined whether or not the use of the toe-gap force measurement makes the sense from practical viewpoint. The usual training for prevention of falls is tried and the change of toe-gap force is examined.

Training group was trained for 5 months, during which the toe-gap force was measured for 3 times, i.e. before the training, after 3 months and 5 months from the on set of training. The results were compared to those of the non-training group.

The training group consists of 42 subjects (age range 75-95 years, mean 83.7±5.4 years, 3 males and 39 females). The non-training group consists of 26 subjects (age range 72-93 years, mean 80.2±4.7 years, 2 males and 24 females).

Before starting the measurement, examinees were well informed of the purpose of the examinations, and the consents were verified.

Right foot and left foot were respectively measured for twice and the best score was adopted. The results between before training and after training for 3 or 5 months were made using Student's t-tests, and decided as significant, with risk of 5 %.

**Results**

Table 1 shows the results of experiment 1 as aged, hight, weight, BMI and the physical status of subjects, lower limb muscular power in terms of the 10 m walking time and the toe-gap force, upper limb muscular power in terms of maximum grip strength.

As the results, it is seen that the measured toe-gap force is closely related to the physical strength of the lower limb and upper limb examined by the conventional measurement. ($p<0.01$)

Fig.4 shows the result of toe-gap force the relationship between the faller group and the non-faller group. The faller group consists of 22 subjects, the non-faller group consists of 60 subjects.

As the result, the non-faller group demonstrated the factor of 1.3 greater toe-gap force compared with the faller group. It found that there are relations at 8% under of the risk rates between the toe-gap force and the falling experience.

Fig.5 shows the change of the toe-gap force by training. In the training group, the toe-gap force increased by 8 % in right foot and by 13 % in left foot ($p<0.01$) after 3 months of the training, and increased by 15 % in right ($p<0.05$) and 18 % in left ($p<0.01$) after 5 months. In the non-training group, there was no improvement (no significant).

**Discussion**

In this study, in order to assess the validity of the toe-gap force measurement device for estimation of risk of fall, comparison with the conventional measurement of physical function was demonstrated. Furthermore, change of the lower limb muscular power by usual training for prevention of fall was examined as positive approach.

As the results of experiment 1, the toe-gap force is closely related to the lower limb muscular power and the upper limb muscular power examined by the conventional measurement. In other words, walking

Table 1 Relationship between toe-gap force and conventional measurement items

| | under 75 years old | 75 years old and over | average | relationship with toe-gap force |
|---|---|---|---|---|
| age | 71.1±2.3 | 81.8±5.0 | 79.6±6.3 | ***, + |
| hight [cm] | 152.5±7.9 | 145.9±7.1 | 147.3±7.8 | NS, + |
| weight [kg] | 51.7±6.8 | 48.2±8.9 | 48.9±8.6 | *, + |
| BMI | 22.3±2.8 | 22.6±3.7 | 22.5±3.5 | NS, NS |
| 10m of normally walking time [s] | 8.77±1.67 | 10.91±3.02 | 10.49±2.93 | −**, −+++ |
| 10m of maximum walking time [s] | 6.57±1.50 | 7.89±1.95 | 7.62±1.93 | −***, −+++ |
| maximum grip strength(right)[kgf] | 23.4±5.2 | 18.6±5.1 | 19.5±5.5 | ***, +++ |
| maximum grip strength(left) [kgf] | 21.6±4.6 | 17.5±5.1 | 18.3±5.3 | ***, +++ |
| toe-gap force(right)[kgf] | 3.11±1.15 | 2.57±1.13 | 2.68±1.15 | |
| toe-gap force(left)[kgf] | 3.18±1.24 | 2.52±1.04 | 2.65±1.11 | |

under 75 years old: 29 people, 75 years old and over: 124 people

Toe-gap force(right)(left): *,+:$p<0.05$, **,++$p<0.01$, ***,+++$p<0.005$

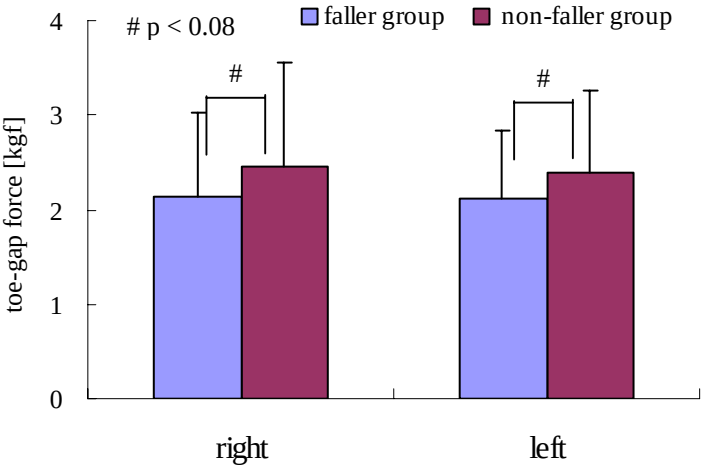


Figure 4 Relationship between toe-gap force and falling experience for one year

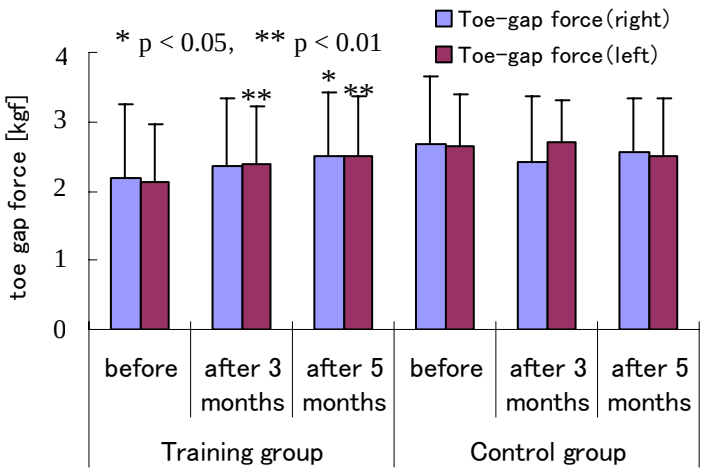


Figure 5 Change of toe-gap force by training

speed is declined, it could presume that the toe-gap force was also declined.

The toe-gap force is generated by work of the tibialis anterior which play important roles in final term of stance phase on walking. In the results, it is considered that as for the toe-gap force is declined, the walking speed becomes slow in relation to a kick of a walk becoming weak.

As the results of Fig.4, the group of experience of fall decreased the toe-gap force compared with the group of non-experience of fall. But this result with risk of 8%, does not satisfy the significant rate in the strict sense.

The reason for having remained in 8% of risk rates is considered that backgrounds, such as a lifestyle and jobs which a subjects has, are related. In a rough view, the subjects who have less toe-gap force have experienced fall. It was suggest that to measure the toe-gap force is effective in rough estimation of falling risk.

As the results of change of toe-gap force by training, the toe-gap force increases significantly in the training group. In many study which intervene training, improvement in lower limb muscular power, such as 10 m walking speed, is not accepted in many cases by falling prevention[9]. It is mentioned that measurement of 10m walking time has large variation and not quantitative as this reason. The method of toe-gap force is quantitative in order to perform static position such as sitting on a chair. This reslut suggests that the improvement of lower limb muscular power is quite exactly reflected on the toe-gap force measurement. In other words, to assess lower limb muscular power for evaluation of risk of fall, it is thought that the toe-gap force is suitable.

## Conclusions

This paper proposed the toe-gap force measurement as a new method to assess the muscular power of lower limb against fall with simplicity and safety at any time and at anywhere, and the result can be shown easily. The proposed device is compact, of light-weight and can examine a large number of the aged in a short time.

It is thus concluded that, the proposed method can be a practically useful method for evaluation quantitatively the function of the lower limb and falling risk of the aged.

It is hoped that the method with help preventing the falling of the aged. The feedback of the result of the measurement may enhance the motivation of aged for training, which will be a subject of study in the future.

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