The Role of Toe-gap Force for the Evaluation of Falling Risk on the Elderly

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Abstract— **This paper was proposed a toe-gap force measurement to estimate the lower limb muscular power. 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 muscles of the lower limb, which are supposed to have roles in the effort against falling. This study was used three experiments to determine whether or not the use of the toe-gap force measurement was useful from a practical viewpoint. First, the aging change in toe-gap force was examined by using the developed measuring device for 361 people included the elderly with physical weakness. Second, to examine the relation between the toe-gap force and falling, we were examined falling experience in a year for 82 healthy volunteers. Third, to examine the relation between muscular power and the toe-gap force, the results of the toe-gap force were compared to the result of the 10 m walking time for 153 healthy volunteers. We found following results: 1. the toe-gap force reflected the lower limb muscular power decrease rapidly from 65 years old. 2. The non-faller group demonstrated the factor of 1.3 greater toe-gap force compared with the faller group. The subjects who have less toe-gap force have experienced many falls. 3. the measured toe-gap force is closely related negative correlation to walking ability. This implies that the lower limb muscular power is reflected on the toe-gap force measurement. It is thus concluded that, the proposed method can be a practically useful method for evaluating quantitatively the lower limb muscular power of the elderly against fall.**

Keywords— **Toe-gap force, lower limb muscular power, elderly, falling prevention**

I. Introduction

Falling is one of the most common and serious problems because advancing age has been associated with muscle weakness, reduced cutaneous sensation and deterioration of postural control system. 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 5% result in any type of fracture[1].

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 reported the decrease of lower limb muscular power and ability of postural control[3-5]. However, the technique and device which evaluate quantitatively lower limb muscular power and ability of postural control are not developed. This paper proposes a toe-gap force measurement as an evaluation of the lower limb muscular power for this purpose.

The major design goals were focused on portability, economy, effectiveness, and convenience which are considered as the result can be clearly shown, in the evaluation of lower limb muscular power. The proposed device was developed so that these conditions might be fulfilled.

The aim of this paper was examined the aging change of lower limb muscular power focused fore part of the feet by the toe-gap force for 361 people (mean 65.1 years old, 3 to 95 years old) included the elderly with physical weakness. Second, we was examined the experience falling for one year, and referred the relation to the toe-gap force. Third, to examine the relation between the toe-gap force and walking ability, the results of the toe-gap force were compared to the results of the 10 m walking time.

II. Materials and Methods

A. Measurement device of toe-gap force

Fig.1 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.2 shows one example of the usage. When the toe-gap force measurement device is used, the subject is seated in front of the device. It is safe because there is no danger of a

falling accident during the measurement process. And it can be easily to measure only one person.

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[6]. 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[4], it is considered that the toe-gap force reflects the muscular power in the lower limb.

These muscles play the important roles in fixing the great-toe as well as in walking, in final term of stance phase[5]. 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.

B. Aging change in the toe-gap force

The aging change in muscular power by the toe-gap force, was examined by using the developed measuring device. Young healthy participans (male: n=29, age:15.0±10.5(3-35 years old) , female: n=45, age:19.1±9.9 (3-44 years old)) , middle age healthy participants (male: n=8, age: 56.9±6.0 (46-64 years old), female: n=13, age:57.5±6.2 (46-64 years old)), elderly healthy participants (male: n=43, age:77.1±5.3 (69-90 years old), female: n=166, age:79.1±6.2 (65-95 years old)) and elderly participants in the physical weakness (male: n=23, age: 79.5±7.3 (66-94 years old, female: n=34, age: 79.9±6.5(69-92 years old)) were recruited from the volunteer.

C. Relationship between toe-gap force and falling experience for one year

There are many reports that a correlation between the experienced fall and the falling risk, so it is important to estimate the falling risk in the future. To examine the relation between toe-gap force and falling, we examined the falling experience for one year. The subjects were 82 healthy volunteers (mean 82.0 years, age range from 72 to 95 years old) in this experiment.

D. Relationship between toe-gap force and walking ability

The toe-gap force was compared with the basic physical function as the walking ability, because there are many reports such as a risk of fall which have relationship between the 10 m walking time and the experience of fall[3-5]. The subjects were 153 healthy volunteers in this experiment.

Fig.1 The measurement device of toe-gap force

Fig.2 Example of how the device is used

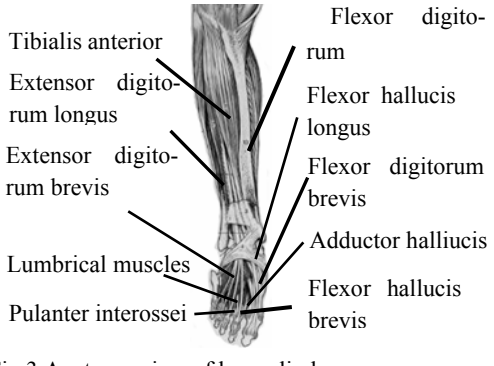

Fig.3 Anatomy view of lower limb

For the assessment of lower limb muscular power, the subjects were divided into two age group as young old (age range from 65 to 74 years old, mean 71.2±2.0 years old,

9 males and 20 females) and old old (age range from 75 to 95 years old, mean 81.8±5.0 years old, 13 males and 111 females).

The comparisons of toe-gap force between faller and non-faller were made using One-factor ANOVA. The results of toe-gap force and 10 m walking ability were made using Wilcoxon sign-ranks test.

III. Results

A. Aging change in the toe-gap force

Fig.4, 5 show the results of aging change in the toe-gap force. As the result, the decrease because of the aging of the toe-gap force was confirmed both male and female.

On an average of toe-gap force in twenties, male is 6.3 kgf, female is 3.9 kgf. On an average from 45 to 64 years old, male is 5.9 kgf (right) and 5.0 kgf (left), female is 3.9 kgf (right) and 3.7 kgf (left). For the young old, male is 3.9 kgf (right) and 3.8 kgf (left), female is 2.8 kgf (right) and 2.9 kgf (left). For the old old, male is 4.0 kgf (right) and 3.8 kgf (left), female is 2.5 kgf (right) and 2.4 kgf (left). For the elderly with physical weakness, male is 2.1 kgf (right) and 1.9 kgf (left), female is 1.9 kgf (right) and 1.6 kgf (left).

It was suggested that the toe-gap force as well as the lower limb muscular power decrease rapidly from 65 years old.

B. Relationship between toe-gap force and falling experience in one year

Fig.6 shows the result of the 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 relationship at 8 % under of the risk rates between the toe-gap force and the experienced fall.

C. Relationship between toe-gap force and walking ability

Table 1 shows the results of the relationship between toe-gap force and 10 m walking time as well as lower limb muscular power and walking ability.

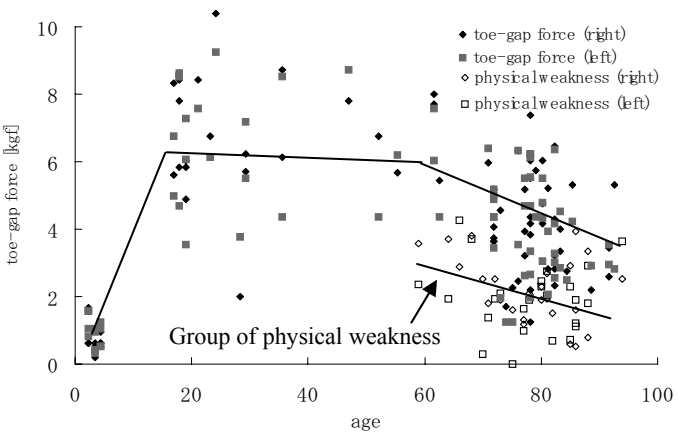

Fig.4 Aging change in the toe-gap force (male)

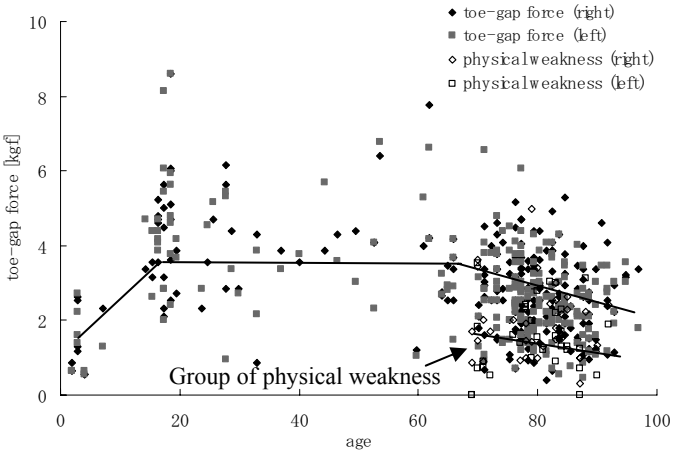

Fig.5 Aging change in the toe-gap force (female)

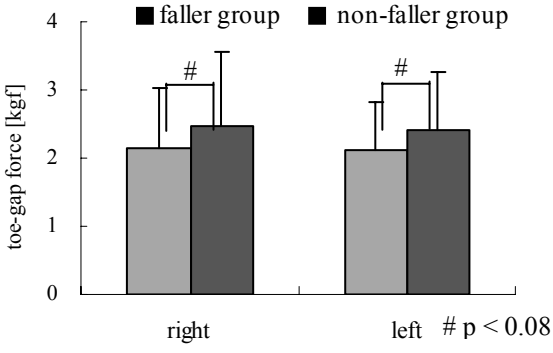

Fig.6 Relationship between toe-gap force and falling experience for one year

Table 1 Relationship between toe-gap force and walking ability

	under 75 years	75 [illegible] and [illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	

* p < 0.01, ** p < 0.005

As the results, it is seen that the measured toe-gap force is closely related negative correlation to the lower limb muscular power and walking ability. The method of measurement of 10 m walking time is semi-quantitative measurement technique, and a lot of disturbances as the psychological hallmark in the subjects, are often generated. And there is a falling risk during the measurement.

On the method of toe-gap force measurement, there is no danger of the fall for this measurement process by the seating. And it is possible to measure it quantitative, safety, everywhere and anytime to use. Moreover, it is a feature that the result is simple and comprehensible.

IV. Discussion and conclusions

In this study, in order to the validity of the toe-gap force measurement device for estimation of risk of fall, were compared with aging change, falling experience and walking ability.

As the results of aging change in the toe-gap force, the aging change is confirmed both male and female. Especially, the toe-gap force decrease rapidly from 65 years old. It is reported that the lower limb muscular power, ability of ambulatory and postural control decrease rapidly from 65 years old. The result similar as for the toe-gap force measured in the fore feet was obtained.

As the results of relationship between toe-gap force and falling experience for one year, the non-faller group demonstrated the factor of 1.3 greater toe-gap force compared with the faller group. The subjects who have less toe-gap force have experienced many falls. It is suggested to be able to use the toe-gap force measurement device when the falling risk is presumed from the viewpoint of the lower limbs muscular power.

As the results of relationship between toe-gap force and walking ability, walking time 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.

It is thus concluded that, the proposed method can be a practically useful method for evaluating quantitatively the lower limb muscular power of the elderly against fall.

Acknowledgment

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