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Reliability of Isometric Knee Extension Muscle Strength Measurement Using a Hand-held Dynamometer with a Belt: A Study of Test-retest Reliability in Healthy Elderly Subjects

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Abstract. [Purpose] The purpose of this research was to study the test-retest reliability of isometric knee extension muscle strength measurement using a hand-held dynamometer (HHD) with a belt, with healthy elderly people living in the community as subjects. [Subjects] The subjects were healthy elderly people living in the community, with an average age of 70.5 years, and measurements were made of the leg on the side that was used to kick a ball. [Method] The subjects sat on a mat table, and isometric knee extension muscle strength measurements using a HHD with a belt were conducted twice, at an interval of 30 seconds, with a knee flexion angle of 90 degrees. The measurement values were classified according to the gender of the subjects, and by age group 65–69 years, 70–74 years, and 75 years and above, and studied. Test-retest reliability was studied using the intraclass correlation coefficient (ICC) and checks of the differentials. [Results] The ICC(1,1) between the first and second measurements ranged from 0.85 to 0.92. Apart from the group of men aged 75 years and above, the second measurement values were higher than those of the first. [Conclusion] Test-retest reliability of isometric knee extension muscle strength measurement using a HHD with a belt was high in healthy elderly persons. However, measuring only once, or measuring twice and taking the average was considered inappropriate, since there is the possibility that the values in such cases would be lower than the actual muscle strength.
Key words: Hand-held dynamometer, Healthy elderly persons, Test-retest reliability

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INTRODUCTION

Muscle strength training is employed as one form of intervention using a variety of methods, with the objective of preventing both falls and the need for care in the elderly. It is common to study the benefits of such training by implementing muscle strength measurement before and after such intervention. When studying the benefits of training, it is necessary to consider the reliability of the muscle strength measurement tests of elderly subjects. In this research, we report on the test-retest reliability of knee strength for both healthy and physically impaired elderly subjects. Callahan et al.[1)] studied test-retest reliability over two times, with an interval of one week, in 58 elderly patients

Table 1. Summary of subjects of isometric knee extension muscle strength measurement using a hand-held dynamometer in conjunction with a belt

Sex	Age group	n	Height (cm)	Weight(kg)	Side measured*
Women	All subjects	113	150.6 ± 6.5	52.4 ± 7.1	108/5
	65–69y	62	152.1 ± 7.3	54.4 ± 6.7	60/2
	70–74y	32	149.6 ± 5.7	51.5 ± 6.5	31/1
	75y–	19	147.7 ± 2.7	47.9 ± 6.7	17/2
Men	All subjects	72	163.6 ± 6.5	62.4 ± 8.0	65/7
	65–69y	34	155.5 ± 10.3	56.1 ± 10.1	29/5
	70–74y	25	163.3 ± 6.7	63.82 ± 8.7	23/2
	75y–	13	158.3 ± 6.1	56.9 ± 8.5	13/0

mean ± SD. *: right/left.

aged 65 years old or above with physical disabilities such as coronary arterial disease and congestive heart failure. They found that, in leg press extension measured by knee extension pneumatic bilateral seated leg press equipment, the intraclass correlation coefficient (ICC) was 0.75–0.97; in knee extension measured by pneumatic strength training equipment the ICC was 0.78–0.92; and in knee extension measured by CYBEXII(90 degrees/second) the ICC was 0.84. Rydwik et al.[2] studied test-retest reliability over two times, with an interval of about one week, in 34 elderly subjects aged 75 years or above. They found that, in muscle strength of the upper thigh measured by a muscle strength training device for the arm/shoulder, Pearson's product moment correlation coefficient was 0.97. Carpenter et al.[3]studied test-retest reliability over two times, with an interval of 6–8 days, in 18 patients with a mild level of osteoarthritis. They found that, in isokinetic knee flexion and extension as measured by the BIODEX Multi-Joint System B2000, the ICC was 0.6037–0.9505, while in isometric knee flexion and extension, the ICC was 0.8121–0.9605.

In the above-mentioned previous research, test-retest reliability was studied with intervals of several days, but test-retest reliability within the same day was not studied. Katoh et al.[4,5] have reported achieving higher reliability among the examiners as well as test–retest reliability by using an HHD with a belt for isometric measurement of lower limb (hip, knee, ankle joint) muscle strength, with healthy subjects with an average age of about 20 years. Among the results, the test–retest reliability for knee extension in two measurements with an interval of 30 seconds, was 0.94–0.96. However, the measurement method of Katoh et al. used healthy people as subjects, and the test–retest reliability for elderly subjects was not studied. The purpose of this research was to study test-retest reliability when measured two times in succession on the same day, in isometric knee extension muscle strength measurement of healthy elderly subjects living in the community.

SUBJECTS AND METHODS

The subjects were 185 healthy elderly people (72 men, 113 women) living in the community who participated in a physical strength measurement organized and publicized by local authorities. They had an average age of 70.5 years (SD=5.2 years), an average height of 155.8 cm (SD=9.0 cm), and an average weight of 56.1 kg (SD=9.1 kg). Measurements were conducted on the leg on the side that kicked a ball (Table 1). None of the subjects had any orthopedic problems or joint pain in the hip, knee, or foot joints on the side being measured. Also, the measurements were conducted after the purpose and contents of this research had been explained to the subjects and their consent had been obtained.

For the HHD, the isometric muscle strength measurement device μTas F-1 (Anima Co., Tokyo) was used. The metal sensor area on the HHD has rubber pads that cover its surface. Velcro straps attached to the sensor area are used to fix the sensors on the part being measured. There is a buckle on the belt to fix the sensors, enabling its length to be adjusted, and a plate attaching the sensors. The range of measurement of the device is 0.0–100.0 kgf with tolerance adjusted to 0.1 kgf or

Table 2. Measurement values of isometric knee extension muscle strength measurement in the elderly, using a hand-held dynamometer in conjunction with a belt

Sex	Age group	n	1st time	2nd time
Women	All subjects	113	20.5 ± 7.1	22.6 ± 7.2*
	65–69y	62	22.4 ± 7.3	24.7 ± 7.1*
	70–74y	32	19.8 ± 6.3	21.6 ± 6.4*
	75y-	19	15.6 ± 5.3	17.3 ± 5.9*
Men	All subjects	72	32.5 ± 11.8	35.7 ± 11.6*
	65–69y	34	35.7 ± 11.5	39.3 ± 12.3*
	70–74y	25	31.0 ± 10.7	34.0 ± 9.1*
	75y–	13	26.1 ± 12.6	28.9 ± 11.2†

mean ± SD(kgf). *: paired t test, $p<0.01$. †: Wilcoxon's signed rank test, not significant.

Table 3. Reliability of isometric knee extension muscle strength measurement in the elderly, using a hand-held dynamometer in conjunction with a belt

Sex	Age group	n	ICC(1,1)	95%CI
Women	All subjects	113	0.88	(0.83-0.92)
	65–69y	62	0.85	(0.76–0.91)
	70–74y	32	0.88	(0.78-0.94)
	75y–	19	0.92	(0.81–0.97)
Men	All subjects	72	0.91	(0.85–0.94)
	65–69y	34	0.90	(0.81–0.95)
	70–74y	25	0.88	(0.76–0.95)
	75y–	13	0.90	(0.72–0.97)

ICC:intraclass correlation coefficient.
95%CI: 95% confidence interval.

less.

The subjects sat on the mat table, and the position of their buttocks was adjusted so that the leg on the mat table was positioned behind the lower limb to be measured. The mat table had a height such that, when the subjects sat on it, both their feet were off the floor. The subjects kept their trunks vertical and put both their hands on the top of the mat table at the sides of their trunks. The examiners laid out bath towels that had been folded under the subjects' popliteal fossa, and set up the subjects so that their thighs were kept horizontal and their lower legs were hanging down, with the knee joint at a flexion angle of 90 degrees. The HHD sensors were placed on the distal anterior surface of the lower thigh, and the lower edge of the sensor was fixed with a hook-and-loop fastener at the height of the upper edge of the malleolus medialis. Then the limb being measured, to which the sensor had been attached, and the leg on the mat table, were linked with a belt. Isometric movement by exerting maximum effort in knee joint extension movement for about five seconds was conducted twice, with an interval of 30 seconds or more between times. During the measurements, the examiner held both sides of the sensor, to maintain the direction of the sensor, so that the surface of the sensor stayed relative to the direction of the movement. After explaining the method, the measurements were conducted twice without practice. The examiner was a man who is knowledgeable about the measurement method employed in this research (age 41 years, height 180 cm, weight 54 kg). Measurements for these tests were recorded by a research assistant, who was not fully informed of the details of the research. The examiner knew neither the age nor measurement values of the subject until all the tests had ended.

The measurement values were classified according to subjects' ages, the 65–69 age group, the 70–74 age group, and the 75 years and above age group, by men and women. Test–retest reliability was studied using the paired t-test or the Wilcoxon signed rank test, and the intraclass correlation coefficient (ICC). Also, the Pearson's product moment correlation coefficient of the rate of increase of the second measurement values [rate of increase: (second measurement values – first measurement values)/first measurement values] in relation to those of the first measurement was studied. For statistics, SPSS ver.15.0J for Windows (SPSS Japan Inc., Tokyo) was used; a difference of less than 5% was considered significant.

RESULTS

The isometric knee extension muscle strength average values, in order of classification (in the order of: all subjects, 65–69 age group, 70–74 age group, 75 and above age group), were, for the first measurement for men, 32.5 kgf, 35.7 kgf, 31.0 kgf and 26.1 kgf, and for the second, 35.7 kgf, 39.3 kgf, 34.0 kgf and 28.9 kgf, respectively; while for the first measurement for women they were 20.5 kgf, 22.4 kgf, 19.8 kgf and 15.6 kgf, and for the second measurement they were 22.6 kgf, 24.7 kgf, 21.6 kgf and 17.3 kgf, respectively (Table 2). In the comparison of the first and second measurements, no significant difference was found in men aged 75

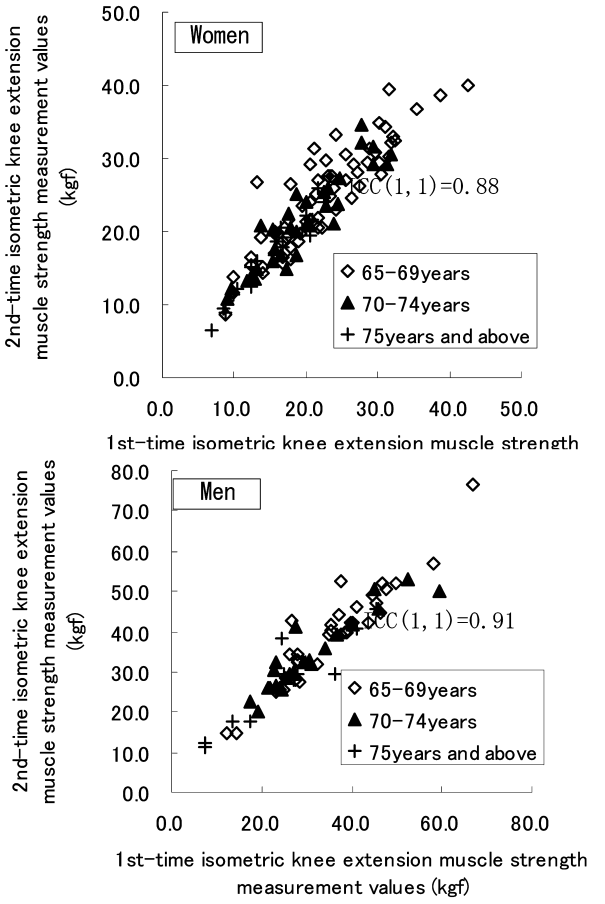

Fig. 1 A comparison of two isometric knee extension muscle strength measurements of the elderly, using a hand-held dynamometer in conjunction with a belt.
The intraclass correlation coefficient [ICC(1,1)] of the first and second times measurements of all subjects showing the relationship between the 1st and 2nd measurement values was 0.91 for men,and 0.88 for women.

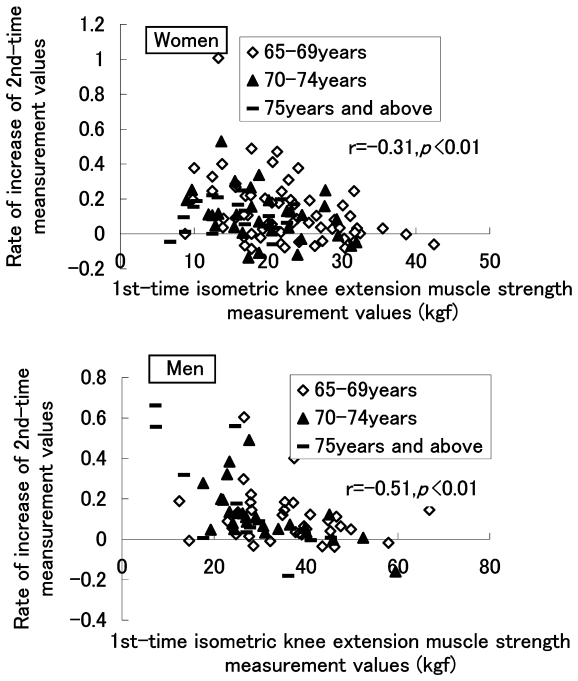

Fig. 2 A comparison of the rate of increase between the first and second isometric knee extension muscle strength measurements of the elderly, using a hand-held dynamometer in conjunction with a belt.
The percentage of subjects showing an increase of 10% or more at the second measurement was 46% for men and 49% for women. The rate of increase of the second measurement over the first was significantly correlated with the first measurement.

years or above, but for all the other age groups for both men and women, a significant difference was found, with the second measurement values being higher than the first ($p<0.01$). The ICC (1, 1) between the first and second measurements, in order of age group, was for men 0.91, 0.90, 0.88 and 0.90, and for women 0.88, 0.85, 0.88 and 0.92, respectively (Table 3, Fig.1). The average rate of increase the second time for men was 0.13 (SD=0.16), and for women 0.12 (SD=0.16). The percentage of subjects for whom the rate of increase the second time compared to the first time was 0.1 or more was 46% for men, and 49% for women, while the percentage of subjects for whom the rate of increase was 0.2 or more was 17% for men and 23% for women. The percentage of subjects for whom there was a 0.1 or greater decrease was 3% for both men and women. The correlation coefficient of the rate of increase and first measurement was $r=-0.51(p<0.01)$ for men, and $r=-0.31(p<0.01)$ for women (Fig.2).

DISCUSSION

The measurement of physical fitness involved a large number of people at a fixed time and had to be conducted within a limited time. The measurement was conducted by appointment. Considering the length of time a subject can afford to spare, it was conducted only twice. Since the measurement was restricted to twice, there was no room for

rehearsing. No two measurements are the same or necessarily close to each other. Accordingly the mean cannot always be relied upon. For this reason the assessment of the reliability of the measurement value is very important. Crum et al.[6] examined the Mini-Mental State Examination Score of the able-bodied according to 5-year age groups. The scores of the aged tended to be lower. It is likely that the subjects' understanding of the measuring method differed with age group. For this reason the data were analyzed with reference to age groups of 65–69, 70–74, 75 and above.

Bohannon[7] conducted isometric knee joint extension muscle strength measurements using an isokinetic movement measuring device (Cybex II), with 20 healthy women with an average age of 29.2 years as subjects. In the test-retest reliability of two measurements at an interval of 30 seconds, an ICC of 0.932 was reported. Katoh et al.[5] conducted isometric knee joint extension muscle strength measurements of 37 healthy subjects with an average age of 21.9 years, using the same method as in this research, and reported the test-retest reliability of two measurements at an interval of 30 seconds had an ICC of 0.94–0.96. In the present research, the ICC ranged from 0.85 to 0.92. The test-retest reliability of isometric knee extension muscle strength measurement of healthy elderly people, using a HHD with a belt, was high, but there appeared to be the possibility that the reliability was slightly lower than that for healthy young subjects.

We consider that, since, apart from men aged 75 years or above, the second measurement values were significantly higher than those of the first, there was a possibility that the measurement values of the first measurement stayed at low values. With regard to the rate of increase of the second measurement, for about half of the subjects it was 10% or more, and a significant negative correlation was found with the first measurement. The method was explained to the subjects, but no practice was performed after the HHD and the belt were attached, before the two measurements were conducted. Therefore, we surmise that there were many subjects who had not mastered the exercise or were not warmed-up sufficiently for the first mesurement, resulting in low measurement values, and that the measurement values increased the second time mainly as a result of learning. Accordingly, we think that, in cases when the difference in measurement values is large, there is a possibility that the average value does not accurately reflect the actual muscle strength. Since some subjects were also seen for whom the measurement values were higher the first time, rather than excluding the first time from the records and regarding the first time as practice, it would be more appropriate to use the higher value from among the two measurement values. However, in cases where higher measurement values were indicated the second time, there is the possibility that conducting measurements three or more times would produce even higher values. There appears to be a need for future study of the test-retest reliability with measurements being conducted three or more times.

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