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Reliability of Isometric Knee Extension Muscle Strength Measurements of Healthy Elderly Subjects Made with a Hand-held Dynamometer and a Belt

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Abstract. [Purpose] The purpose of this study was to examine the reliability of three isometric knee extension strength measurements (IKE) made with a hand-held dynamometer (HHD) and a belt of healthy elderly living in the community as subjects. [Subjects] The subject cohort consisted of 186 healthy elderly people, aged 65 to 79 years, living in local communities. [Methods] IKE of the leg subjects used to kick a ball was measured. IKE of each subject was measured three times using an HHD-belt at intervals of 30 seconds. The reliability of the larger of the first two measurements (LV2) as well as the third measurement (3V) was investigated. [Results] The intraclass correlation coefficients [ICC (1, 1)] for LV2 and 3V were 0.955. Bland-Altman analysis showed a fixed bias, and the limits of agreement ranged from −5.6 to 4.6. [Conclusion] The ICC results show that the test-retest reproducibility of IKE measurements of healthy elderly subjects using an HHD-belt is high. However, Bland-Altman analysis showed a fixed bias, suggesting the need for three measurements.

Key words: Hand-held dynamometer, Healthy elderly subjects, Knee extension muscle strength

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INTRODUCTION

Various physical functions deteriorate with age, and the word sarcopenia is clinically used to describe this age-related decrease in muscle mass[1)]. Based on previous studies[2–6)], the consensus statement of the European Working Group on Sarcopenia in Older People (EWGSOP) notes that a diagnosis of sarcopenia requires reductions in muscle mass and muscle function (muscle strength and physical capabilities). The muscle strength of the lower limbs can be assessed by evaluating standing up from a chair[7, 8)], gait[9–15)], going up and down stairs[8)], and by falls[16, 17)]. Most intervention studies aimed at preventing elderly people from falling include training to strengthen the muscles of the lower limbs[18–38)].

The muscle strength of the lower limbs can be assessed quantitatively by measuring the isometric knee extension strength with the knee joints flexed at 90 degrees. A hand-held dynamometer (HHD) is a tool that is relatively easy to operate and is frequently used to quantify muscle strength. However, holding an HHD in the hand may limit subjects' performance in the task being tested. The upper limit of measurement using an HHD was found to be 30 kg, regardless of measurement experience and ability to apply resistance[39)]. Fixation was reported to be difficult to achieve at or above 300 N[40)], and at 85 N/m or higher[41)]. An investigation of 36 Japanese subjects found that the average maximum weight loads that male and female testers were able to measure 27.6 kg and 19.0 kg, respectively, much lower than those reported previously[42)].

The primary disadvantage of measurements with HHD alone is that the investigators do not usually have the upper limb strength to fully restrain the subjects. To overcome this disadvantage, a method using a belt with an HHD was developed to measure the muscle strength of the lower limbs[43–45)]. The reproducibility and adequacy of the HHD alone and with a belt (HHD-belt) in measuring muscle strength has been compared in healthy males and females aged approximately 20 years[43–45)]. The reproducibility of measurements of knee extension muscle strength has been investigated among investigators, between measurement methods, and between test-retests[43)]. The intraclass correlation coefficients (ICC) between investigators [ICC (2, 1)] were 0.04 without a belt and 0.98 with a HHD-belt, and Pearson's product moment correlation coefficient between the measurement methods was 0.61 for male investigators and 0.31 for female investigators. The ICCs (1, 1) between test-retest were 0.94, 0.96 and 0.96 for three trials and 0.89 among the three trials[44)]. A comparison of the HHD-belt method with an isokinetic muscle strength measurement device yielded a Pearson's product moment correlation coefficient for isometric knee extension muscle strength of 0.75[45)].

The test-retest reproducibility of measurements of iso-

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metric knee extension muscle strength has also been estimated for hemiplegic patients, for patients who had received surgery for femoral head fractures, and for healthy elderly people[46–48]. The ICCs (1, 1) for hemiplegic patients, obtained from 3 measurements performed on the same day were 0.98 for session 1 and 0.99 for session 2 on both the paralyzed and non-paralyzed sides[46]. For patients who had received surgery for femoral head fractures, the ICCs (1, 1) on the same day were 0.948 for the fractured leg, 0.953 for the non-fractured leg and 0.961 for the average of both legs[47]. The ICCs (1, 1) for healthy elderly males and females, from two measurements on the same day were 0.91 and 0.88, respectively[48]. An increase of 10% was observed in the second measurement for approximately 50% of the healthy elderly subjects, suggesting the necessity of basing ICCs on three consecutive measurements[48].

If the third measurement of healthy elderly subjects were higher than the second, then the third measurement may be more appropriate. However, performing three measurements requires more time and a larger number of investigators. Therefore, comparing the second and third of three consecutive measurements of healthy elderly subjects may elicit information about the adequacy and practicality of these measurements.

The purpose of this study was to examine the reliability of three consecutive isometric knee extension strength measurements (IKE) made with a hand-held dynamometer and a belt of healthy elderly subjects living in the community.

SUBJECTS AND METHODS

The study cohort comprised 186 of 235 healthy elderly people living in local communities who participated in physical strength test programs in 2010 and 2011 organized by the government of a city with a population of about 250,000 people. Subjects were excluded if they <65 or >79 years old, if they had participated in a similar program in 2009 or earlier, if they had knee joint pain, or if they had any other diseases or pain conditions that would have affected measurements of muscle strength. If a subject had participated in the program in both 2010 and 2011, the values obtained in 2010 were analyzed. The 186 subjects comprised of 66 males with an average height of 163.6 cm (SD = 6.0 cm) and an average body weight of 61.4 kg (SD = 6.7 kg), and 120 females with an average height of 150.9 cm (SD = 4.8 cm) and an average body weight of 52.3 kg (SD = 6.4 kg). The subjects were divided into three age groups, 65 to 69, 70 to 74, and 75 to 79 years, as shown in Table 1. Approval was obtained from the research ethics committee of Ryotokuji University and from the city administration, which had organized the physical strength test program, to use the data for this study. All subjects provided their written informed consent.

Isometric knee extension muscle strength was measured using a μTas F-1 hand-held dynamometer (Anima Corp., Tokyo, Japan). Subjects sat on a training bench and adjusted the position of their gluteal regions so that leg of bench was posterior to the lower limb being measured. The leg measured was that used to kick a ball. The height of the training bench was set so that each subject's legs were slightly above the floor. Subjects maintained their trunk in a perpendicular position with both hands touching the bench surface on either side of the trunk. A large folded towel was placed under the popliteal fossa of each subject, with one femur maintained horizontally with the knee joint set at an angle of 90 degrees, and both lower legs hung perpendicular to the floor.

Table 1. Subject group profiles

Gender	Age group (yrs)	n	Height (cm)		Weight (kg)	
Female		120	150.9	(4.8)	52.3	(6.4)
	65 to 69	75	151.1	(4.3)	51.9	(6.2)
	70 to 74	37	150.8	(5.2)	53.2	(7.4)
	75 to 79	8	149.9	(7.2)	52.5	(2.8)
Male		66	163.6	(6.0)	61.4	(6.7)
	65 to 69	29	164.5	(5.8)	60.9	(5.8)
	70 to 74	29	163.4	(6.7)	61.5	(8.7)
	75 to 79	8	161.0	(3.4)	63.2	(4.9)

Mean (SD)

The HHD sensors was placed on the distal anterior surface of the lower leg, and the lower edge of the HHD was fixed with a hook-and-loop fastener at the height of the upper edge of the malleolus medialis. A belt was placed over the HHD and tied to the leg of a bed. Maximum effort in knee joint extension movement was exerted for about five seconds and repeated twice more at intervals of ≥30 seconds between exertions. The examiner was a man, of height 180 cm and weight 54 kg, highly familiar with this method of measuring, but he was not informed of the results. In addition, the research assistant who recorded the results was blinded to the purpose of the research.

The larger of the first two measurements (LV2) was utilized. The difference between the third measurement (3V) and LV2 [Δ3V=3V-LV2] and the ratio of Δ3V to body weight (Δ3V/BW) were calculated. The results of all the study subjects and of the three age groups were analyzed.

The necessity of performing the third measurement was assessed by determining ICC (1, 1) for LV2 and 3V as well as by Bland-Altman analysis. SPSS ver.15.0 J for Windows and R2.8.1 were used for statistical analyses; p-values <0.05 were considered statistically significant.

RESULTS

The average values for all subjects were 31.9 kgf for LV2, 32.4 kgf for 3V, 0.5 kgf for Δ3V, and 0.010 kgf/kg for Δ3V/BW (Table 2). Increases in Δ3V and in Δ3V/BW, as well as the numbers of proportion of subjects showing increases in each group, are shown in Tables 3 and 4. For 54.8% of all subjects, the 3V measurements were higher than LV2. In addition, 11.3% of the study subjects showed Δ3V increases of ≥5 kgf, and 2.7% showed increases of ≥10 kgf (Table 3). Moreover, Δ3V/BW increased by ≥0.05 kgf/kg (5% of body weight) in 16.7% of these subjects and by ≥0.100 kgf/kg

Table 2. Isometric knee extension muscle strength values of elderly people, as measured by a hand-held dynamometer with a belt

Age group (yrs)	n	LV2[a)]		3Vb[b)]		Δ3V[c)]		Δ3V/BW[d)]	
		kgf		kgf		kgf		kgf/kg	
All subjects	186	31.9	(10.1)	32.4	(10.1)	0.5	(3.0)	0.010	(0.054)
65 to 69	104	31.2	(9.9)	32.0	(10.1)	0.5	(3.4)	0.015	(0.049)
70 to 74	66	39.8	(9.8)	40.2	(8.9)	0.4	(2.7)	0.011	(0.059)
75 to 79	16	29.7	(10.2)	31.0	(10.3)	−1.3	(3.5)	−0.023	(0.064)

Mean (SD), [a)] The largest value of the first two measurements, [b)] The value of the third measurement, [c)] 3V-LV2, [d)]Δ3V/body weight

Table 3. Increase from the largest value out of the first two measurements to the value of the third measurement (Δ3V*)

Age group (yrs)	n	0 kgf<		5 kgf≤		10 kgf≤		15 kgf≤		20 kgf≤
All subjects	186	102	(54.8)	21	(11.3)	5	(2.7)	1	(0.5)	0
65 to 69	104	63	(60.6)	14	(13.5)	5	(4.8)	1	(1.0)	0
70 to 74	66	33	(50.0)	7	(10.6)	0				
75 to 79	16	6	(37.5)	0						

No. of subjects (proportions shown in percent), *The value obtained in the third measurement − The largest value out of the first two obtained measurements

Table 4. Increase from the largest value out of the first two obtained measurements to the value of the third measurement, divided by bodyweight (Δ3V/BW#)

Age group (yrs)	n	0.000<		0.050≤		0.100≤		0.150≤		0.200≤
All subjects	186	102	(54.8)	31	(16.7)	10	(5.4)	2	(1.1)	0
65 to 69	104	63	(60.6)	18	(17.3)	5	(4.8)	1	(1.0)	0
70 to 74	66	33	(50.0)	13	(19.7)	5	(7.6)	1	(1.5)	0
75 to 79	16	6	(37.5)	0						

No. of subjects (proportions shown in percent), #(The value obtained in the third measurement − The largest value out of the first two obtained measurements) / Body

Table 5. Reliability of the largest value out of the first two measurements, and the value in the third measurement

Age group (yrs)	n	ICC (1,1)		Bland-Altman analysis					
		point estimation	95% CI	LOA	fixed bias		proportional bias		
					95% CI	bias*	slope**		bias*
All subjects	186	0.955	(0.940–0.966)	−5.6–4.6	−0.4–−0.6	exist	0.004	p=0.83	n-ex
65 to 69	104	0.955	(0.940–0.966)	−5.4–3.7	−0.7–−1.0	exist	−0.210	p=0.45	n-ex
70 to 74	66	0.957	(0.938–0.970)	−5.0–4.1	−0.2–−0.6	exist	0.022	p=0.56	n-ex
75 to 79	16	0.937	(0.834–0.977)	−2.5–5.1	−0.1–−0.5	exist	0.008	p=0.93	n-ex

ICC: intraclass correlation coefficient, 95% CI: 95% coefficient interval, LOA: limits of agreement, *: presence of bias, exist: present, n-ex: not-present, **: Slope of regression line

(10% of body weight) in 5.4% (Table 4).

The results of ICC and Bland-Altman analysis of LV2 and 3V are shown in Table 5. ICC (1, 1) of all subjects was 0.955 and was 0.9 or higher for all three age groups (Table 5). Bland-Altman analysis showed a fixed bias, with limits of agreement for all subjects between −5.6 and 4.6 (Table 5 and Fig. 1).

DISCUSSION

Physical strength measurement programs for healthy elderly people are run by the city administration, both to prevent elderly people from requiring nursing care and to improve their health. Individuals are invited to participate in these programs at places such as community centers. These programs are designed to assess as many individuals as possible in a short period of time, making it necessary to minimize the time spent assessing each participant.

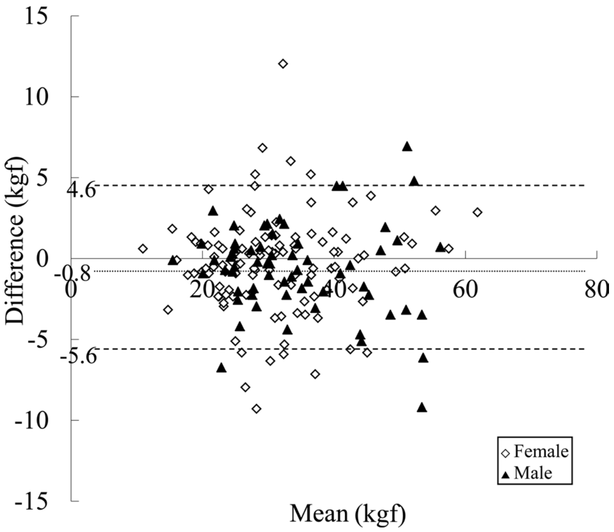

Fig. 1. Bland-Altman analysis using the largest value out of the first two measurements, and the value of the third measurement

An investigation of the reproducibility of two sets of measurements of 183 healthy elderly subjects who participated in a physical strength measurement program run by a city administration found that the ICC (1, 1) for the two measurements was 0.91 for males and 0.88 for females[47]. However, 46% of males and 49% of females showed increases of ≥10% in the second measurement, and 17% and 23%, respectively, showed increases of ≥20%. These results led to our use of the higher of the values obtained in the two sets of measurements, and indicated the necessity of performing three consecutive sets of measurements.

The results presented here indicate that high reproducibility can be obtained when three measurements are performed, because the ICCs for LV2 and 3V were ≥0.9 for both males and females. However, the highest values for at least 50% of the study participants were obtained in the 3V measurement. Moreover, a comparison of LV2 and 3V found that 16.7% of subjects showed an increase of ≥0.050 kgf/kg in 3V. Therefore, limiting the number of measurements to two may yield lower than actual muscle strengths for more than half the subjects, and lead to the bodyweight ratio being recorded at least 0.050 kgf/kg lower, equivalent to 5% of bodyweight, for 1 in 6 subjects. A lower than actual bodyweight ratio in knee extension muscle strength can affect the interpretation of relationships between muscle strength and motions such as gait. These findings suggest that performing three measurement trials is appropriate for gaining more accurate measurements of IKE of healthy elderly people.

Bland-Altman analysis found a fixed bias with negative values, with LV2 lower than 3V, and a range of +5.6 kgf and −4.6 kgf for two measurements.

An investigation of Mini-Mental State Examination Scores of different age groups, intervals of 5 years, found that the scores decreased with age[49]. Since the IKE of our study subjects may also decrease with age, subjects were divided into three age groups, 65 to 69, 70 to 74, and 75 to 79 years. None of the subjects in the 75 to 79-year-old group showed increases in Δ3V of ≥5.0 kgf or in Δ3V/BW of ≥0.050 kgf/kg. We hypothesize that increases in the third measurement are smaller in this age group than in the other age groups, suggesting that the third measurement may not be required for subjects aged 75 to 79 years.

Further increases in the number of measurements should be considered for subjects aged 65 to 74 years, since a higher proportion of subjects in this group than in the other group showed the highest measured value in the third measurement. However, time constraints may preclude four or more measurements per subject.

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