

Comparison of quadriceps setting strength and knee extension strength tests to evaluate lower limb muscle strength based on health-related physical fitness values in elderly people

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ABSTRACT

Objective Conventionally, knee extension strength is often used as the indicator for lower limb muscle strength; however, several recent studies have also used quadriceps setting strength. This study aimed to investigate and compare the association of quadriceps setting and knee extension strength with health-related physical fitness.

Methods We evaluated quadriceps setting strength and isometric knee extension strength in 75 elderly subjects (mean age, 76.8±5.3 years) to determine their lower limb muscle strength. Health-related physical fitness was evaluated using the physical fitness test advocated by the Ministry of Education and Culture, Sports, Science and Technology in Japan. The test consists of the following components: grip strength, sit-up, sit and reach, one leg standing with eyes open, 10 m obstacle walk and 6 min walk.

Results When adjusted for age, sex and body mass index, quadriceps setting strength was significantly correlated with grip strength, number of sit-ups, sit and reach distance, 10 m obstacle walking time and 6 min walking distance. In contrast, knee extension strength was associated only with grip strength and number of sit-ups.

Conclusion More health-related physical fitness parameters with quadriceps setting strength than knee extension strength. Quadriceps setting strength may be superior to knee extension strength as a predictor of health-related physical fitness.

What are the new findings?

- ⇒ Quadriceps setting strength is associated with various physical fitness tests (grip strength, sit-up, sit and reach, 10 m obstacle walk and 6 min walk), independently of age, sex and body mass index (BMI).
- ⇒ When adjusted for age, sex and BMI, knee extension strength is related only to the grip strength and sit-up tests.
- ⇒ Health-related physical fitness has a stronger association with quadriceps setting strength than with knee extension strength.

related to activities of daily living (ADL) than other parameters.^{6 7}

Quadriceps setting strength is an alternative measurement used to determine lower limb muscle strength.⁸ It is measured through the quadriceps setting exercise, which involves training of the quadriceps femoris muscle. Interestingly, Inoue *et al*⁹ investigated the association between lower limb muscle strength and gait in elderly individuals and found that quadriceps setting strength was the most important determinant of walking speed compared with other muscles of the lower limb. This suggests that quadriceps setting strength may be more strongly associated with physical function than other parameters used to evaluate lower limb muscle strength. However, few studies have clarified the usefulness of using quadriceps setting strength in this regard.

Understanding the best way to measure lower limb muscle strength is important to ensure early detection and prevention of decline in the physical function of elderly individuals. In addition, it is important to determine the overall physical fitness of elderly people. Health-related physical fitness, which consists of four domains including strength and endurance of muscle, flexibility,



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INTRODUCTION

Muscle weakness can affect the physical independence of elderly people. The age-related loss of lower limb muscle strength is associated with poor functional performance,¹ physical disability,^{2 3} falls⁴ and mortality.⁵ Several parameters such as hip abductor muscle strength, knee flexion and extension muscle strength are used to evaluate lower limb muscle strength. In particular, knee extension muscle strength is often adopted to evaluate lower limb muscle strength because knee extension strength is more strongly

cardiorespiratory fitness and body composition, is essential for having healthy daily lives of elderly individuals.^{10,11} Therefore, the aim of the present study was to investigate and compare how closely the quadriceps setting and knee extension strength values relate to health-related physical fitness.

METHODS

Subjects of the study

The subjects were 75 (23 men and 52 women) community-dwelling elderly people. They belonged to a senior club in Kyoto and volunteered to participate in a physical fitness test held by the club. Recruitment was conducted through information posted on bulletin boards, circular notices and websites. The inclusion criteria for this study were as follows: (1) age ≥ 65 years, (2) valid measurements of quadriceps setting strength and isometric knee extension strength and (3) living at home, with the capacity of self-care. Informed consent was obtained from all subjects.

Measurements of lower limb muscle strength

Lower limb muscle strength was determined by measuring quadriceps setting and knee extension strength. The muscle strength in the right and left legs was measured twice after a trial measurement. The highest value of the two measurements was registered and used for analysis.

Quadriceps setting strength was measured using a Locomoscan device (Alcare Co Ltd, Tokyo, Japan).^{8,12} As shown in [figure 1](#), a force sensor was placed in the popliteal fossa in a long sitting position. The distal leg participating in the movement was fixed using a belt. The subjects were asked to extend the knee with maximum force.

Knee extension strength was measured using a custom-made dynamometer chair, as previously described.¹³ The ankle was attached via a belt to a dynamometer (T.K.K.5710e, Takei Scientific Instruments Co Ltd, Niigata, Japan). The subjects were in a sitting position with the hip and knee flexed 90° and were required to extend the knee with maximum force.

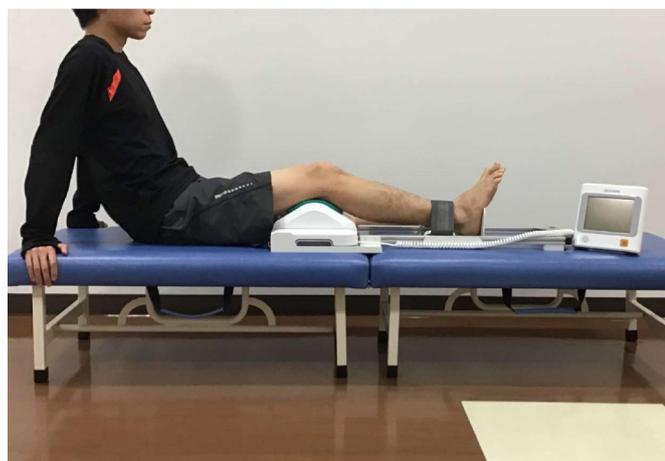


Figure 1 Quadriceps setting strength measuring system.

Measurements of health-related physical fitness

Health-related physical fitness was evaluated using the physical fitness test for elderly individuals, which was approved by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in Japan.¹⁴ This test emphasises the measurement of health-related physical fitness and consists of six tests: grip strength, sit-up, sit and reach, one leg standing with eyes open, 10 m obstacle walk, and 6 min walk. These were measured in accordance with the guidelines of the MEXT in Japan.¹⁴

Statistical analysis

The relationship between lower limb muscle strength (quadriceps setting and knee extension strength) and health-related physical fitness (grip strength, sit-up, sit and reach, one leg standing with eyes open, 10 m obstacle walk and 6 min walk) was assessed using the Pearson's correlation coefficients. In addition, the partial correlation coefficients adjusted for age, sex and body mass index (BMI) were used. The 95% CIs were calculated for the correlation and partial correlation coefficients. The data were analysed using IBM SPSS Statistics V.25.0 (IBM Corp, Armonk, New York, USA). The level of statistical significance was set at $p < 0.05$.

RESULTS

The characteristics of the subjects and results obtained in each individual tests are shown in [table 1](#).

On average, men had higher measurements than women for height, weight, knee extension strength, grip strength and 6 min walking distance; however, men had shorter 10 m obstacle walking time than women.

The correlation coefficients between quadriceps setting strength, knee extension strength and individual tests of the health-related physical fitness assessment are shown in [table 2](#).

Quadriceps setting strength was significantly associated with grip strength, number of sit-ups, sit and reach distance, one leg standing time, 10 m obstacle walking time and 6 min walking distance. knee extension strength was only significantly related with grip strength, number of sit-ups, 10 m obstacle walking time and 6 min walking distance.

The partial correlation coefficients between quadriceps setting and knee extension strength with individual test of the health-related physical fitness assessment are shown in [table 3](#).

When age, sex and BMI were defined as control variables, both quadriceps setting and knee extension strength were significantly correlated with grip strength and number of sit-ups. However, when adjusting for age, sex and BMI, quadriceps setting strength significantly correlated with the sit and reach distance, 10 m obstacle walking time and 6 min walking distance, whereas knee extension strength was not significantly associated with any of these tests.

DISCUSSION

Lower limb muscle strength generates a propulsive force forward during walking, playing a role in supporting the

Table 1 Characteristics of the subjects and results of each test of the health-related physical fitness assessment

	Men (n=23)	Women (n=52)	All (n=75)
Age (years)	79±4.3	75.9±5.5	76.8±5.3
Height (cm)	165.6±5.6	151±4.8	155.5±8.5
Weight (kg)	62.9±6.9	52.2±7.1	55.5±8.6
BMI (kg/m ²)	22.9±2.3	22.8±2.5	22.9±2.4
Muscle strength			
Quadriceps setting strength (kgf)	39.2±11	34.1±13.1	35.6±12.7
Knee extension strength (kgf)	30.4±7.6	19.6±5.4	22.8±7.9
Physical fitness test			
Grip strength (kg)	33±5.7	21±4.6	24.7±7.5
Number of sit-ups (times)	10.3±6.7	7.9±7.2	8.6±7.1
Sit and reach distance (cm)	31.4±12	34.4±8.5	33.5±9.7
One leg standing time (s)	74.1±49.6	68.9±48.3	70.5±48.4
10 m obstacle walking time (s)	7.1±1.2	8.2±1.5	7.8±1.5
6 min walking distance (m)	603.8±89.1	551.9±68.3	567.1±78
BMI, body mass index.			

lower limb. Previous studies have reported that lower limb muscle strength is related to balance and walking ability.^{15–18} This study showed that quadriceps setting and knee extension strength were significantly associated with health-related physical fitness; however, the coefficient of quadriceps setting strength was higher than that of knee extension strength, with the exception of grip strength and number of sit-ups. The difference in muscles and joints mobilised when exerting muscular strength may

affect the results of this study. Previous studies reported that not only the quadriceps femoris muscle but also the hip extensor muscles, such as the hamstrings and gluteus maximus, are active in quadriceps setting exercises.^{19 20} Therefore, it is considered that quadriceps setting strength requires cooperation of multiple muscles because both the knee and hip joints are extended when exerting quadriceps setting strength. In contrast, only the knee joint is extended when knee extension strength is exerted. Some studies have shown that lower limb muscle strength by multijoint movements had stronger relationships with physical performance and ADLs than lower limb muscle strength by single-joint movements.^{21 22}

The 10 m obstacle walk and 6 min walk tests evaluated the functional walking ability of the subjects. The 10 m obstacle walk requires a high dynamic balance ability to support the body with a single leg when straddling an obstacle. Brown *et al*²³ showed that avoiding obstacles in daily life poses a risk of falls among elderly individuals. In addition, falls are a significant cause of mortality in older adults.^{24 25} The 6 min walk measures the cardiorespiratory fitness and associates with diseases such as diabetes and cardiovascular disease.^{26 27} In the present study, we found that these tests, related to not only walking ability but also the risk factors for falls and various diseases, showed a stronger association with quadriceps setting strength than with knee extension strength.

The measurement of quadriceps setting strength is easy because the device used to measure it is readily movable, and the test can be performed in a small space.⁸ The ability to measure the physical fitness of elderly individuals at locations other than hospitals and research institutes makes it possible to evaluate a higher number of people. From the viewpoint of early detection and primary prevention, an indicator that can detect a decline in physical function in a healthy population and can be measured easily is invaluable. Hence, when using quadriceps setting strength to evaluate physical function in elderly individuals, it can become a valuable parameter to detect a decline in the physical function at an early stage.

Table 2 Single correlation between quadriceps setting and knee extension strength with individual test of the health-related physical fitness assessment

	Quadriceps setting strength				Knee extension strength			
	r	95% CI		p	r	95% CI		p
		Lower	Upper			Lower	Upper	
Grip strength	0.498	0.306	0.651	<0.001	0.769	0.657	0.848	<0.001
Sit-up	0.326	0.107	0.515	0.005	0.385	0.173	0.563	0.001
Sit and reach	0.238	0.012	0.441	0.041	-0.013	-0.239	0.215	0.910
One leg standing time with eyes open	0.289	0.066	0.484	0.013	0.196	-0.032	0.405	0.095
10 m obstacle walking time	-0.512	-0.662	-0.323	<0.001	-0.459	-0.621	-0.259	<0.001
6 min walking distance	0.510	0.320	0.661	<0.001	0.468	0.270	0.628	<0.001
'r' refers to Pearson correlation coefficient.								

Table 3 Partial correlation between quadriceps setting and knee extension strength with individual test of the health-related physical fitness assessment

	Quadriceps setting strength				Knee extension strength			
	r	95% CI		p	r	95% CI		p
		Lower	Upper			Lower	Upper	
Grip strength	0.441	0.238	0.607	<0.001	0.485	0.290	0.641	<0.001
Number of sit-ups	0.226	0.107	0.465	0.025	0.346	0.129	0.531	0.003
Sit and reach distance	0.282	0.059	0.478	0.017	0.082	-0.148	0.303	0.498
One leg standing time	0.168	-0.061	0.381	0.160	0.095	-0.135	0.315	0.431
10 m obstacle walking time	-0.391	-0.568	-0.180	0.001	-0.220	-0.426	0.007	0.066
6 min walking distance	0.353	0.137	0.537	0.003	0.236	0.010	0.439	0.053

'r' refers to partial correlation coefficient (adjusted for age, sex, and BMI)

BMI, body mass index.

The present study has several limitations. We cannot assume that the subjects of the present study represent the general elderly population in Japan, owing to sampling bias. In addition, the number of subjects in our study was small. Nevertheless, our findings provide a foundation for larger prospective studies to determine a relationship between quadriceps setting strength and health-related physical fitness in elderly individuals.

CONCLUSION

We clarified that health-related physical fitness has a stronger association with quadriceps setting strength than with knee extension strength, which is often used to evaluate lower limb muscle strength. Our findings suggest that quadriceps setting strength can, therefore, be useful in the early detection of the decline in physical function.

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