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Original Article

The Relative Importance of Velocity and Strength Components in Physical Tasks for Older Women in Geriatric Health Services Facilities

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SUMMARY

Background: Many studies have shown that muscle power (power = velocity × strength) is a critical determinant of physical tasks, such as gait and sit to stand, in older adults. However, it is still unclear whether velocity or strength has a stronger effect on physical tasks. This study aimed to examine the relative importance of velocity and strength components in determining inter-individual differences in gait and sit-to-stand tasks.
Methods: The participants were 43 female older adults who were residing in geriatric health service facilities (mean age 87.4 years). We measured participants' gait speed, sit-to-stand ability using the five-times sit-to-stand test, movement velocity of knee extension, and quadriceps strength.
Results: Gait speed was significantly associated with movement velocity ($r = 0.38$; $p = 0.013$), but there was no significant association with quadriceps strength. Movement velocity was selected as the independent variable for gait speed in multiple regression analysis. The five-times sit-to-stand test result was not significantly associated with movement velocity, but it was significantly associated with quadriceps strength ($r = -0.50$; $p = 0.016$). Quadriceps strength was selected as the independent variable for sit to stand in multiple regression analysis.
Conclusions: The results suggest that the relative importance of velocity and strength components varies depending on the physical task. These differences may be attributed to the intensity of the physical task.

1. Introduction

Physical tasks (e.g., gait and sit to stand) are indispensable for the maintenance of independent living in older adults.[1–3] Previous studies have reported that muscular strength is an important factor defining these tasks.[4–6] Similarly, muscle power is also an influential determinant of physical tasks, and its effect is greater than that of muscle strength.[7] As muscle power is the product of velocity and strength (power = velocity × strength),[8] both strength and velocity components are relevant determinants of muscle power.

With regard to gait, muscle power at 40% of maximum muscle strength load in the leg press (when velocity is high and load is low) explained gait performance better than muscle power at 70% of maximum strength (when velocity is low and load is high), in community-dwelling older adults.[9] Furthermore, in patients with knee osteoarthritis, muscle power at 40% of maximum strength in knee extension explained gait performance better than muscle power at 70% of maximum strength or 90% of maximum strength.[10] These studies indicated that muscle power at low loads is strongly related to gait tasks.

With regard to the sit-to-stand task, muscle power at 90% of maximum strength in the leg press demonstrated the strongest relationship to the sit-to-stand task rather than muscle power at 40% of maximum strength and peak power.[11] Thus, muscle power at high loads may be strongly related to the sit-to-stand task.

Differences in the load at muscle power measurement affect the relationships between physical tasks and muscle power. Based on the force-velocity curve,[12] the proportion of the velocity component of muscle power is larger when the load is lower. Conversely, the proportion of the strength component is larger when the load is higher. Therefore, gait and sit-to-stand tasks may be more strongly associated with the velocity and strength components of power, respectively.

Because of the difficulty in clearly dividing muscle power into velocity and strength components, it is challenging to determine which component is more important for each physical task. Therefore, the purpose of the current study was to investigate whether the velocity component (the movement velocity that mitigates the strength component as much as possible) or the strength component (the isometric muscle strength excluding the velocity component) is more important for gait or sit to stand in older adults. Determining which component of muscle power (velocity or strength) is more affected by the physical task will be useful in designing rehabilitation programs.

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2. Patients and methods

2.1. Participants

This observational study of older adults in geriatric health service facilities was conducted from August 2014 to November 2017, and all measurements were evaluated by six physical therapists. The participants were 43 female older adults who were residing in one of three geriatric health service facilities. The inclusion criteria were as follows: (i) age $\geq$ 65 years; (ii) ability to walk at least 8 m with or without an assistive device; and (iii) ability to understand and follow our instructions. This study was approved by the Human Ethics Committee of Osaka Prefecture University, and participants gave written informed consent.

The sample size was calculated using G*Power 3.1 (University of Dusseldorf, Dusseldorf, Germany).[13] A minimum of 29 participants was required in order for this study to have acceptable power (power = 80%, α = 0.05). An effect size was set to 0.50 from the correlation coefficient between the sit-to-stand test and quadriceps strength of a previous study.[14] Taking into consideration the potential dropout rate, the final sample size included 43 older adults.

2.2 Measurements of physical tasks

Gait speed was measured on an 8-m walkway, and the initial and final 1.5-m sections were not timed to allow for acceleration and deceleration. Participants were instructed to walk as fast as possible. The time taken to walk the middle 5 m of the walkway was measured using a stopwatch. The gait speed was measured twice, and the fastest time was used for analyses.[15]

The five-times sit-to-stand test was performed using an armless chair.[11] Participants were instructed to rise from a chair five times as quickly as possible with their arms folded across their chest. Timing with a stopwatch began with the command "go" and ceased when subjects achieved their final stand up. The five-times sit-to-stand test was only measured once.[16]

2.3. Measurements of knee joint function

The movement velocity of knee extension was measured as described by Arai et al.[17] A gyroscope (45 mm $\times$ 25 mm $\times$ 15 mm, MicroStone Inc., Saku, Japan) and 2-kg ankle weights were fixed on the distal position of the subject's tibia. The subjects were asked to sit in a chair with their knees and hips at 90 degrees of flexion and to keep their trunk upright. The subjects were instructed to extend their knee as quickly as possible. The movement velocity was measured five times, with the faster of the five movement velocities used for analyses.

Isometric quadriceps strength was measured with a hand-held dynamometer. The subject being tested remained in the sitting position, with the hip and knee at approximately 90 degrees of flexion.[18] Quadriceps strength was measured twice. The strongest measurement was used for analyses.

2.3. Statistical analysis

Pearson's correlation coefficients were used to assess the relationships among the gait speed, five-times sit-to-stand test result, movement velocity of knee extension, and quadriceps strength. Multiple linear regression analysis with forced entry was conducted to determine which independent variables (movement velocity of knee extension or quadriceps strength) were significant predictors of the gait speed and five-times sit-to-stand test result. All analyses were performed using SPSS Statistics 24 (IBM Japan, Ltd., Tokyo, Japan), and p-values < 0.05 were considered significant. Post-hoc statistical power was calculated using G*Power (version 3.1.9.3).[13]

3. Results

Participants' characteristics are presented in Table 1. Overall, 72.1% (31/43) of participants were categorized as having a slow gait speed (less than 1.00 m/s). Additionally, 46.5% of participants (20/43) could not perform the five-times sit-to-stand test without using their upper limbs.

Simple correlation coefficients for the relationships between the various parameters are shown in Table 2. The results of gait speed were moderately correlated with movement velocity of knee extension (power = 0.73). The results of the five-times sit-to-stand test were moderately correlated with quadriceps strength (power = 0.71).

Multiple regression analysis was performed with gait speed and the five-times sit-to-stand test result as dependent variables, and movement velocity of knee extension and quadriceps strength as independent variables (Table 3). The independent variables accounted for 13.9% of variance in gait speed and 21.6% of that in the five-times sit-to-stand test result. Movement velocity was a significant predictor of gait speed, and quadriceps strength was a significant predictor of the five-times sit-to-stand test result.

4. Discussion

The results showed that gait speed was significantly associated with movement velocity of knee extension but not quadriceps strength. In contrast, the five-times sit-to-stand test result was significantly associated with quadriceps strength but not with movement velocity of knee extension. In multiple regression analysis, movement velocity and quadriceps strength were selected as

Table 1
Characteristics of the study population.

Characteristic	n	Value
Age (years)	43	87.4 $\pm$ 5.9
Height (cm)	43	143.2 $\pm$ 9.1
Weight (kg)	43	42.4 $\pm$ 6.9
Ambulatory assistance, n (%)		
None		11 (25.6)
Cane		6 (14.0)
Walker		26 (60.5)
Mobility		
Gait speed (m/s)	43	0.81 $\pm$ 0.30
Five-times sit-to-stand test (s)	23	16.5 $\pm$ 7.4
Movement velocity		
Lower limbs (deg/s)	43	276.5 $\pm$ 68.4
Muscle strength		
Quadriceps strength (kg)	43	10.4 $\pm$ 4.1

Mean $\pm$ standard deviation (SD).

Table 2
Correlation of movement velocity, mobility, muscle strength.

	Gait speed		STS	
	r	p value	r	p value
Movement velocity of lower limbs	0.38	0.013	-0.32	0.144
Quadriceps strength	0.30	0.055	-0.50	0.016

STS: five-times sit-to-stand test.

Table 3
Results of multiple regression analysis.

Independent variable	Gait speed		STS	
	Adjusted β	p value	Adjusted β	p value
Movement velocity of lower limbs	0.32	0.040	-0.21	0.298
Quadriceps strength	0.20	0.186	-0.45	0.032
	Ajusted R^2 = 0.139		Ajusted R^2 = 0.216	

STS: five-times sit-to-stand test.

the independent variables for gait speed and five-times sit to stand test, respectively. We demonstrated that the physical task determines the relative importance of velocity and strength components.

The gait task is affected by various factors. For instance, quadriceps strength affects gait speed.[19,20] Nevertheless, many studies have shown that the relationship between quadriceps strength and gait speed is only weak to moderate.[21,22] Furthermore, other studies have reported a lack of association between these factors in older adults.[23] As these studies showed only a weak relationship between gait speed and quadriceps strength, our findings that gait speed and quadriceps strength were not significantly related are not surprising. However, movement velocity is correlated with mobility tasks, and this correlation becomes stronger when the external loading is decreased.[24] The movement velocity of the leg press at 40% of maximum strength is a stronger predictor of gait speed than muscle strength.[25] The movement velocity of knee extension also has a stronger relationship with gait speed than with muscle strength.[17] The results of this study are in line with previous findings that movement velocity is more related to gait speed than quadriceps strength.

It has been reported that quadriceps strength is significantly correlated with the sit-to-stand task in older adults.[26,27] The results of the present study are in agreement with previous findings. This correlation is dependent on the fact that quadriceps strength requires vertical movement during the sit-to-stand task.[14] As such, many studies have reported the relationship between quadriceps strength and sit-to-stand movement, whereas the effect of movement velocity of lower limbs on sit-to-stand has not been investigated.

The degree of influence of velocity and strength components differed with regard to the type of tasks used in this study. Knee muscle power during sit to stand is more than double of that during gait.[28] The quadriceps strength required for the gait and sit-to-stand tasks were 21–38% of maximum strength[29] and 78% of maximum strength,[30] respectively. Thus, gait and sit-to-stand tasks can be defined as low-intensity and high-intensity physical tasks, respectively. Based on the load-velocity relationship,[31] the intensity of the physical task can be defined as being the same as the load. Therefore, the velocity component appears to be important for low-intensity physical tasks, whereas the strength component seems to be important for high-intensity physical tasks.

In older adults who were residing in geriatric health services facilities, mobility was markedly reduced compared to that of healthy older adults.[32,33] As these tasks are strongly associated with independence during activities of daily living,[1,2] it is essential to understand the factors that affect these tasks. Therefore, we selected older adults in geriatric health services facilities as subjects. However, the importance of movement velocity of knee extension changes with advancing age and with lower mobility function.[34] In addition, the contribution of quadriceps strength to the measurement of power differs with age. Therefore, it must be noted that the results may differ if a different experimental sample is used.

There were several limitations in this study. First, the sample size was relatively small, which limited the power of data analysis. It is possible that a statistically significant difference will exist with a larger sample size. Second, each type of walking assistive device was not investigated in this study. Further research is required to investigate whether a walking assistive device affects the relationship between physical tasks and the velocity and strength components. Third, we did not measure physical tasks other than gait speed and the sit-to-stand task. In order to clarify the relationship between physical tasks of different intensities with velocity and strength components more extensively, it will be necessary to measure other physical tasks.

In conclusion, regardless of the type or intensity of the physical task, muscle strength of the lower limbs is important for the performance of physical tasks in older adults. Herein, movement velocity explained much of the variance in gait ability, whereas muscle strength explained much of the variance in sit-to-stand ability in older adults who were residing in geriatric health service facilities. These results suggest that the relative importance of velocity and strength components varies depending on the physical task. Therefore, examining movement velocity may also be important for understanding the cause of deterioration of physical task performance.

Declarations of interest

None.

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