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Research Article
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Characteristics of Movement Velocities of Upper and Lower Limbs and Trunk in Older Adults

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Abstract

Objective: Lower limb movement velocity is a good predictor of mobility in older adults. The movement velocities of the trunk and upper limbs are also good determinants of mobility. However, the reason for this is not clear, possibly because the basic characteristics of the movement velocities are still unclear. To investigate these characteristics, we evaluated the associations between the movement velocities of all three body regions and between these velocities and mobility measurements.

Methods: One hundred twelve community-dwelling older adults (mean age 74.1 years) participated in this study. We measured the movement velocities (lower limbs, upper limbs and trunk), muscle strength (knee extensor, trunk extensor and plantar flexor), mobility measures (gait speed and timed up and go test (TUG)), and gait parameters (step length and cadence).

Results: All movement velocities were moderately correlated with each other (r=-0.42 to 0.61). All movement velocities were also significantly associated with mobility to the same degree as muscle strength (gait speed r=-0.42 to 0.51, TUG r=-0.37 to 0.57). A stepwise regression analysis revealed that the movement velocities of the upper and lower limbs were significant predictors of gait speed, while that of the trunk was an independent predictor of TUG. Movement velocities were associated with step length more than with cadence.

Conclusion: These findings indicate that movement velocities can be treated as individual values and considered good indicators of mobility in older adults, regardless of body region.

Keywords: Movement velocity; Gait speed; Timed up and go test; Muscle strength

Introduction

The prevention or postponement of mobility limitations among older adults is of major public health importance. The reasons for mobility limitations with aging are multifactorial. Above all, muscle power is closely related to mobility in older adults [1]. Muscle power is defined as muscular work per unit of time [2], and declines earlier and more rapidly than muscle strength with advancing age [3]. Muscle power is a more critical determinant of mobility than muscle strength in older adults [4]. Because muscle power is the product of force and velocity (power = force × velocity) and movement velocity is an increasingly important determinant of maximal power with aging [5], a decrease in movement velocity would lead to a decreased capacity to generate muscle power in older adults.

Movement velocity in the leg press exercise has been shown to be a stronger predictor of performance of lower intensity functional tasks such as gait speed than muscle strength [6]. Movement velocity of the knee extensor is significantly correlated with gait speed in older women [7], and these correlations became stronger when external loadings decreased and the movement velocity consequently increased [8]. In addition to the lower limbs, the movement velocities of the trunk and upper limbs were also significantly associated with mobility in our previous studies [9,10]. Moreover, the movement velocities of all regions were lower in fallers than in non-fallers among community-dwelling older adults [11].

Although it is clear that movement velocities are important for mobility in older adults, it is still unclear why and how the movement velocities relate with mobility. We think this is because of an insufficient basic understanding of movement velocities, including whether the movement velocities of regions are related to each other, which regions with movement velocity have strong effects on mobility, and which parameters of gait are affected by movement velocities.

Therefore, we conducted this study to examine the following questions: (1) the relationships between the movement velocities of the lower limbs, the upper limbs, and the trunk; and (2) the relationships between these movement velocities and mobility measures or gait parameters.

Materials and Methods

Participants

A total of 112 community-dwelling older adults participated in this study. The participants were recruited through local senior centers. The inclusion criteria were: 1) age ≥ 60 years; 2) able to walk 10 m; 3) able to understand and follow our instructions. The Human Ethics Committee of Osaka Prefecture University approved this study (approval number: 2010-01), and written informed consent was obtained from all participants.

Measurements

Mobility measures and gait parameters: We measured maximum gait speed using a floor-based photocell gait analysis system (OPTOJUMP, Microgait, Bolzano, Italy) over an 8 m walkway in the laboratory. Maximum gait speed was determined by recording the time it took to walk the central 5 m of 8 m. The initial and final 1.5 m sections were not timed to allow for acceleration and deceleration. Step length and cadence were measured as gait parameters and all parameters were also measured by the OPTOJUMP system.

The timed up and go test (TUG) was performed as reported by Podsiadlo and Richardson [12]. The test is a timed measure that assesses the participant's ability to rise from a chair, walk 3 m at their usual speed, cross a line, walk back, and sit down again. Both performance tests were performed twice after a practice trial, and the best time was used for the subsequent analysis.

Movement velocities measures: We measured the movement velocities of three regions; lower limbs, upper limbs, and trunk. Movement velocity of the lower limbs was measured according to the methods of Van Roie et al [8]. The velocity was measured by determining the angular velocity of knee extension using an isokinetic dynamometer (Biodex, Biodex Corp., Shirley, NY). The participants were asked to extend the knee joint as quickly as possible from knee joint angle 90° to 160° without external resistance on the lever arm. Movement velocity of the upper limbs was determined by quickness of upper limb movement in a standing position. The details of this method have been described previously [10]. Briefly, the participants were instructed to move a small and plastic box 30 cm laterally as fast as possible using their dominant hand, and we measured the time taken using a precision timer. Movement velocity of the trunk was measured using one part of the Seated Side Tapping test (SST), as previously described [11]. The test requires the participants to move their bodies laterally ten times in turn as quickly as possible while in a seated position. The time required between the first and second tapping was measured using a touch sensor.

Muscle strength measures: The isometric muscle strength of three muscle groups was measured in this study: knee extensor, plantar flexor and trunk extensor. The knee extensor strength was measured with participants sitting and their knee joint flexed at 90° flexion using a Biodex [13]. Participants were instructed to plantarflex with as much force as possible, and the strength was measured using a hand-held dynamometer (μTas F-1, Anima, Tokyo, Japan), positioned at the level of the first metatarsal head. To perform the trunk extensor strength test, the participant was positioned prone on a treatment table with an experimenter restraining their lower body against the table. They were instructed to lift their upper body to the vertical with their arms crossed in front of their chest, and another experimenter measured their strength while maintaining this posture, using a hand-held dynamometer placed at the level of the spine of the scapula. If the participants could not lift their upper body due to pain or discomfort, the data were not analyzed. Each muscle strength test was performed twice after a practice trial, and the best result was used for the subsequent analysis.

Statistical analyses: Pearson's correlation coefficients were used to assess the relationship between age, movement velocities (lower limbs, upper limbs and trunk) and muscle strengths (knee extensor, plantar flexor, and trunk extensor). Correlation coefficients were calculated between age, movement velocities and mobility measures (maximum gait speed and TUG). A forward stepwise multiple linear regression analysis was conducted, with the mobility measures (maximum gait speed and TUG) as dependent variables, and age, sex, body mass index (BMI), movement velocities (lower limbs, upper limbs, and trunk), and muscle strength measures (knee extensor, plantar flexor, and trunk extensor) as independent variables. Moreover, we investigated the relationships between movement velocities and gait parameters (step length and cadence). All analyses were performed using SPSS Statistics, version 22 (SPSS Japan, Inc., Tokyo, Japan), and p-values <0.05 were considered significant.

Results

A total of 112 older adults participated in this study. The characteristics of the participants are presented in Table 1. Their mean age was 74.1 ± 6.0 years, and 25.0% of the participants were male. The mean maximum gait speed was 1.9 ± 0.3 m/sec, and the mean TUG time was 6.8 ± 1.3 seconds.

	Characteristics	n	Value	Range
Physical characteristics	Age (years)	112	74.1 ± 6.0	60-88
	Male, n (%)	112	28 (25.0)	
	Height (cm)	112	154.0 ± 7.3	141.3-172.6
	Weight (kg)	112	51.4 ± 7.5	32.3-70.6
	Body mass index (kg/m^2)	112	21.7 ± 2.9	15.5-32.0
Mobility measures	Maximum Gait Speed (m/sec)	112	1.9 ± 0.3	1.1-2.6
	Timed Up and Go test (sec)	112	6.8 ± 1.3	4.5-11.3

Movement velocity	Lower limbs (degree/sec)	107*	402.9 ± 43.0	282.0-488.5
	Upper limbs (m/sec)	112	3.3 ± 0.6	1.9-4.9
	Trunk (sec)	111**	0.56 ± 0.11	0.33-0.98
Muscle strength	Knee extensor strength (Nm)	107*	92.2 ± 32.0	31.1-260.9
	Trunk extensor strength (kg)	105***	15.0 ± 5.4	23.4-88.3
	Plantar flexor strength (kg)	112	50.3 ± 14.3	0.6-31.5

*No data for five participants, due to their experiencing pain or discomfort during measurements.

**No data for one participant, due to missing data.

***No data for seven participants, due to their experiencing pain or discomfort during measurements.

Table 1: Characteristics of the subjects (n = 112).

Pearson's correlation coefficients between age, movement velocities and muscle strengths are shown in Table 2. All three measures of movement velocities were significantly and moderately correlated with each other, and these parameters were also significantly correlated with age and all measures of muscle strengths.

		Movement Velocity			Muscle Strength		
		Lower limbs	**Upper limbs**	**Trunk**	**Knee extensor**	**Trunk extensor**	**Plantar flexor**
Age		-0.47**	-0.39**	0.39**	-0.34**	-0.53**	-0.34**
Movement Velocity	Lower limbs	-	0.61**	-0.42**	0.69**	0.55**	0.48**
	Upper limbs	0.61**	-	-0.45**	0.6**	0.48**	0.47**
	Trunk	-0.42**	-0.45**	-	-0.31**	-0.36**	-0.26**
Muscle Strength	Knee extensor	0.69**	0.6**	-0.31**	-	0.47**	0.57**
	Trunk extensor	0.55**	0.48**	-0.36**	0.47**	-	0.48**
	Plantar flexor	0.48**	0.47**	-0.26**	0.57**	0.48**	-

Table 2: Correlations between age, movement velocities and muscle strengths (**P<0.01).

All muscle strength measurements were also correlated with each other. Table 3 shows the correlations between age, movement velocities, muscle strengths and mobility measures. All measures of movement velocities were significantly correlated with maximum gait speed and TUG. Age and all muscle strengths were also correlated significantly with mobility measures. In the final model of the stepwise multiple regression analysis, the upper and lower limb movement velocities, plantar flexor strength, and BMI were each independently associated with maximum gait speed (Table 4).

		Mobility	
		Gait speed	**TUG**
	Age	-0.37**	0.47**
Movement velocity	Lower limbs	0.51**	-0.46**
	Upper limbs	0.48**	-0.37**
	Trunk	-0.42**	0.57**
Muscle strength	Knee extensor	0.41**	-0.25**
	Trunk extensor	0.39**	-0.43**

	Plantar flexor	0.49**	-0.45**

Table 3: Correlations between age, movement velocities and Mobility measures (**P<0.01).

The model explained 38% of the variance in maximum gait speed. This analysis also showed that the movement velocity of the trunk, plantar flexor strength, and age contributed independently to TUG, accounting for 47% of the variance.

Dependent variables	Independent variables	β	P	VIF	R^2
Maximum gait speed	Movement velocity of upper limbs	0.26	0.01	1.67	0.38
	Plantar flexor strength	0.26	0.01	1.42	
	BMI	−0.24	0	1.01	
	Movement velocity of lower limbs	0.23	0.02	1.64	
TUG	Movement velocity of trunk	0.43	0	1.22	0.47
	Plantar flexor strength	−0.25	0	1.16	
	Age	0.25	0	1.26	

Table 4: Stepwise multiple linear regression analysis, with gait speed and TUG as dependent variables.

The correlation coefficients between movement velocities and gait parameters are presented in Table 5. Although step length was significantly associated with all measures of movement velocities, cadence was associated with only movement velocity of the trunk.

		Step length (cm)	Cadence (steps/sec)
Movement velocity	Lower limbs	0.52**	0.13**
	Upper limbs	0.5**	0.12**
	Trunk	-0.29	-0.28**

Table 5: Correlations between movement velocities and gait parameters.

Discussion

We investigated the associations among the movement velocities of various body regions, muscle strength, mobility measures, and gait parameters, to determine the basic characteristics of movement velocities in community-dwelling older adults. This enabled us to identify three characteristics of movement velocities in this study.

First, movement velocity of any region can be used as an indicator of total body movement velocity status. In this study, all three movement velocity measurements were moderately correlated with each other (r=-0.42 to 0.61), as were the muscle strength measurements (r=0.47 to 0.57). Moderate correlations between different muscle strength measures have also been shown in previous studies [14,15], and in many studies a measure of strength for one body region, such as grip strength, is treated as an indicator of total body strength [16,17]. Because the degrees of relationships among movement velocities are approximately the same as muscle strengths, movement velocity of any region can be used as an individual representative value like hand grip strength.

Secondly, regardless of the region, movement velocity can be used as a predictor of mobility measures. Although our previous studies revealed that the movement velocity of not only the lower limbs but also those of the upper limbs and trunk are associated with mobility, we could not compare directly the influence of movement velocity of upper limbs, lower limbs and trunk on mobility measures [9,10]. Therefore, the relationships between movement velocities of each region and mobility measures were still unclear. In this study, all movement velocities were significantly correlated with gait speed (r=0.42 to 0.51) and TUG (r=-0.37 to -0.57). Moreover, all movement velocities were significant independent predictors of gait speed or TUG in stepwise regression analyses. These results show that the differences in the degrees of relationships between all movement velocities and mobility measures are relatively small and all movement velocities are good predictors of mobility in older adults.

In addition to these three characteristics of movement velocities, we also observed that age was significantly associated with all movement velocities. The reduction in movement velocities of the lower limb joints, such as plantar flex and knee extension, with age was shown in a previous review [18]. The present study revealed that the upper limbs and trunk had the same tendency with the lower limbs. These results indicate that the movement velocities decrease with aging regardless of the region of the body.

On the other hand, the results of stepwise regression analysis revealed the difference in three movement velocities. The movement velocity of lower and upper limbs is independent predictors of maximum gait speed, whereas movement velocity of trunk is that of

TUG. TUG is composed of multiple movement tasks, such as standing up, walking, turning and sitting down [19]. Because the trunk control is a crucial factor for controlling the center of gravity while standing up and sitting down especially in older people [20,21], the movement velocity of trunk might be selected as a significant predictor of TUG. In other words, the relationship between movement velocities of body regions and mobility measures may change depending on the specificity of the mobility task. Further research is necessary on this point.

Thirdly, the movement velocities were associated with step length more than cadence in this study. Step length is predicted by the muscle power of the lower limbs during motion, such as ankle plantar flexor muscle and hip extensor muscle powers [22,23]. Movement velocity is one factor involved in muscle power, and it may be the reason why a significant correlation between movement velocity and step length was seen. The decline in gait speed with aging is apparently the result of a decrease in step or stride length rather than a decrease in cadence [24]. Based on the significant correlation between movement velocity of any region and step length, training focused on movement velocity may improve step length and lead to improvements in mobility measures.

There were several potential limitations of this study. The male to female ratio of participants was 1:3. There are gender differences in mobility measures [25] and the movement velocity of the lower limbs [6], which may limit the generalization of our results. Further research is required to analyze the correlation of these parameters, separated by gender. Another limitation was that the participants in this study were relatively healthy. The effect of movement velocity on functional performance in older adults differs between healthy individuals and those with mobility limitations [5]. Accordingly, the mobility level of the participants may have influenced the results.

Conclusion

The movement velocity of one body region reflects total body movement velocity status and mobility level in older adults. Therefore, movement velocity can be treated as individual values and a single movement velocity measure can be assumed to be adequate, as for muscle strength measures. Although several studies have indicated that training focused on movement velocity is an effective intervention for improving mobility in older adults [26-28], the methods and conditions in these studies varied widely. The results of this study suggest that the most important region movement velocity may change depending on the mobility tasks. Therefore, when planning the training focused on movement velocity, it may be necessary to consider the relationship between the movement velocity of a region and mobility tasks. On the basis of our results, for example, training focused on the movement velocity of the trunk may be more effective for sit-to-stand movement than for gait. Our findings will be useful for developing such training methods.

Conflicts of Interest

All authors declare that they have no conflict of interest.

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