

Preliminary study on the effects of movement velocity training of the upper limbs on gait ability in older adults: a nonrandomized controlled trial

This article was published in the following Dove Press journal:
Clinical Interventions in Aging

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Purpose: Movement velocity of the limbs or trunk plays an important determinant of gait speed in older adults. Movement velocity-focused training of the lower limbs or trunk has recently been shown to be an effective intervention to improve gait ability. Because movement velocities of various body regions are significantly correlated, movement velocity training of the upper limbs may also be effective for improving gait speed. Therefore, the purpose of this study was to investigate whether movement velocity training of the upper limbs in a seated position is effective for improving gait ability.

Patients and methods: This study was a nonrandomized controlled trial. The participants were older adults residing in geriatric health service facilities. They were assigned to the movement velocity training of the upper limbs group (n=26) or control group (n=15). The participants in the training group performed exercises (three times per week for 10 weeks) to move the upper limbs as quickly as possible. The outcomes were gait speed, movement velocity, and quadriceps strength. These measurements were performed preintervention and 4, 8, and 10 weeks after intervention.

Results: A significant time-group interaction was found for maximum gait speed and movement velocity of the upper limbs. Bonferroni post-hoc test showed significant improvement in gait speed between preintervention and 10 weeks after intervention in the training group. The movement velocity of the upper limbs was significantly improved between preintervention and 4, 8, and 10 weeks after intervention.

Conclusion: Movement velocity training of the upper limbs showed significant and clinically relevant improvements in maximum gait speed at 10 weeks after intervention. This training is a potentially useful intervention and can be safely performed.

Keywords: older people, movement velocity training, arm, gait speed, seated position

Introduction

Gait speed is a useful predictor of falls, hospitalization, activities of daily living disability, and survival in older adults.¹⁻⁴ Gait speed is affected by various factors such as age,⁵ gender,⁶ muscle strength,⁷ and muscle power.⁸ In addition to these factors, movement velocity, which is defined by the speed to move the limbs or trunk as fast as possible, plays an important determinant of gait speed in older adults.⁹⁻¹² Movement velocity of the lower limbs (knee extensor and ankle planter flexor) was reported to be more correlated with gait speed compared with quadriceps strength.^{9,10} Movement velocity of the trunk is also significantly associated with gait speed.¹¹ Moreover, movement velocity is a significant determinant of gait

speed even in the upper limbs.¹² Therefore, movement velocity regardless of any body region is a good determinant of gait speed.

Many studies have investigated the influence of complex training of various body parts focusing on movement velocity on gait speed.^{13,14} For example, movement velocity training of the upper and lower limbs (leg extension, bench press, ball throwing, countermovement jump, curl up, and back extension) is effective in improving gait ability.¹³ Furthermore, movement velocity training with no load of the upper and lower limbs (seated row, chest press, shoulder press, biceps curl, triceps extension, knee extension, and knee curl) is effective for improving gait speed compared with traditional muscle strength training.¹⁴ In addition to these complex training programs, movement velocity training of one part of the body is also effective for improving gait speed. Movement velocity training of the lower limbs using an ergometer has been reported to significantly improve gait speed.¹⁵ We previously clarified that the seated side tapping training, which focuses on trunk movement velocity, is an effective intervention to improve gait ability in patients with total knee arthroplasty.¹⁶ These findings indicated that both complex training and one-part movement velocity training have good effects on improving gait. In addition, a significant and moderate correlation is observed between movement velocities of various body regions ($r = -0.42$ – 0.61).¹⁷

Based on these findings, movement velocity has three characteristics. First, movement velocities of any body part are related to gait ability. Second, movement velocity training of the lower limbs or trunk improves gait ability. Third, movement velocities are moderately correlated with each other. Because the movement velocities of different body regions are related to each other and movement training of the lower limbs and trunk is effective for gait improvement, movement velocity training that focuses on the upper limbs may also be effective for improving gait speed.

Movement velocity training of the upper limbs can be carried out in a seated position; thus, the risk of falls is much lower than training in a standing position or walking. Furthermore, the patients who cannot load their body weight on their legs due to pain or load restriction can perform the training safely. In this study, we aimed to investigate whether movement velocity training of the upper limbs in a seated position is effective for improving gait ability.

Material and methods

Study design and participants

This study was a nonrandomized controlled trial. Participants were recruited by physical therapists from three geriatric health services facilities in Osaka, Japan. The inclusion criteria of the study were as follows: 1) older adults in geriatric health service facilities; 2) aged ≥ 65 years; 3) the ability to walk at least 8 m with or without an assistive device; 4) the ability to rise from a chair; and 5) the ability to understand and follow instructions. Participants assigned to the training and control groups were recruited between August 2014 and October 2016 and between September 2015 and August 2018, respectively. We set the interval of recruitments more than one year at each facility to wait for the turnover of facility residents. Both groups do not contain the same participants. This study conformed to the ethical principles contained in the Declaration of Helsinki, and was approved by the Human Ethics Committee of Osaka Prefecture University (approval number: 2014–104). All participants gave written informed consent.

Intervention

Movement velocity training of the upper limbs was conducted three times a week for 10 weeks. The training consisted of five types of exercise to move as fast as possible, and no external load was carried other than the items used (a Japanese fan, towel, and stick). Each exercise comprised the following: 1) shoulder horizontal flexion/extension exercise using a Japanese fan (three sets of 10 repetitions); 2) shoulder flexion/extension exercise using a Japanese fan (three sets of 10 repetitions); 3) shoulder horizontal flexion/extension exercise using a towel (three sets of 10 s); (4) shoulder flexion exercise using a stick (five sets of 10 repetitions); and 5) elbow extension exercise using a stick (five sets of 10 repetitions) (Figure 1). Each training was conducted for approximately 20 mins, including stretching of the upper limbs and light exercise (stepping in sitting position). Participants were instructed to move the entire range of motion as fast as possible.

Measurements

Measurements of mobility

To assess gait speeds, the participants were instructed to walk along an 8-m walkway at their maximal and usual speeds. The 1.5-m space at each end of the walkway for

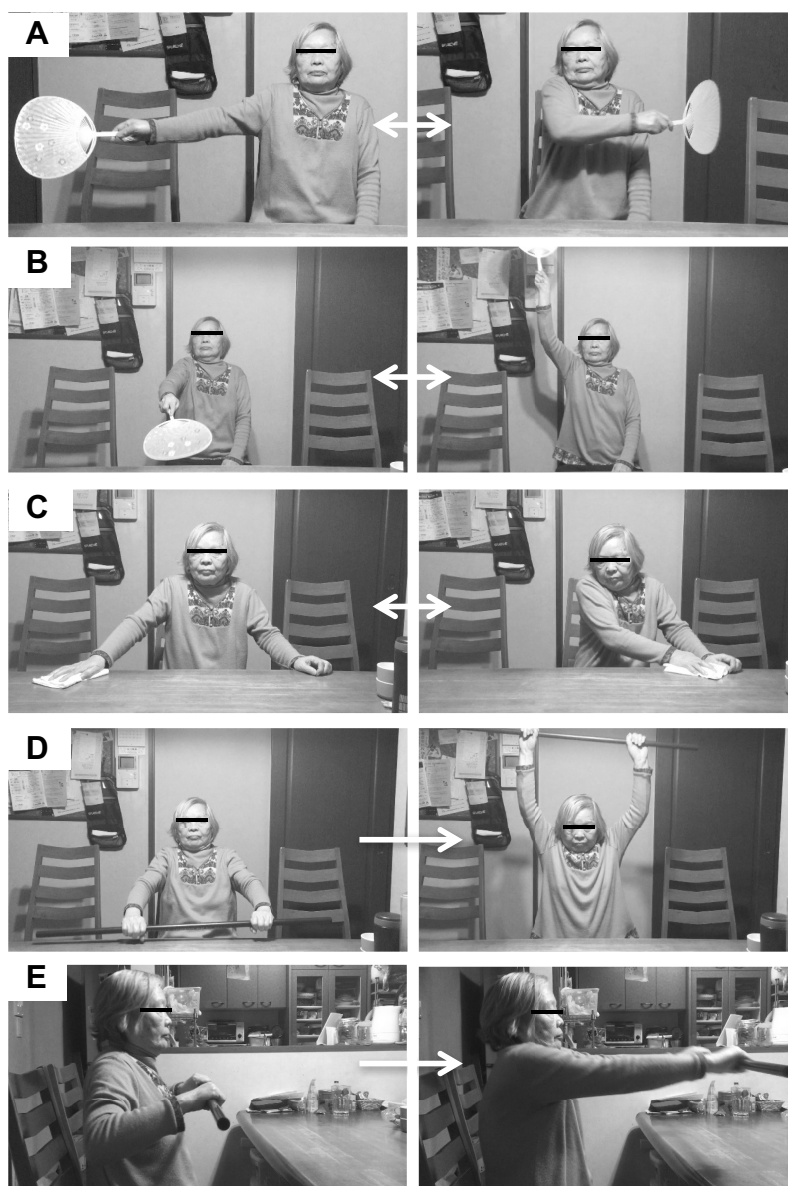


Figure 1 Movement velocity training of the upper limbs. (A) Shoulder horizontal flexion/extension exercise using a Japanese fan. (B) Shoulder flexion/extension exercise using a Japanese fan. (C) Shoulder horizontal flexion/extension exercise using a towel. (D) Shoulder flexion exercise using a stick. (E) Elbow extension exercise using a stick.

acceleration and deceleration was not timed.¹¹ Maximum and usual gait speeds were measured twice using a stopwatch, and the fastest time was used for analyses.

Timed up and go (TUG) was measured using the method described by Podsiadlo and Richardson.¹⁸ Before the measurement, the examiner demonstrated how to perform the TUG and then instructed the participants to stand up, walk 3-m at their usual speed, cross a line, turn around, walk back, and sit down again. The participants were also encouraged to wear their regular footwear and use their walking aids.

The short physical performance battery (SPPB) was evaluated by measuring three physical performance tasks:

usual gait speed, maintenance of standing balance, and sit to stand test.¹⁹ The corresponding tasks include walking at usual speed over 4 m, three static positions with decreasing base of support to challenge balance, and the ability to rise from a chair without the use of the arms five times as rapidly as possible. Result from each test was ranked using a 0–4 scale, and participants who showed high abilities had higher total scores.

Measurements of movement velocity

Movement velocity of the upper limbs measured the time required to move a small plastic box (90 mm × 60 mm ×

20 mm, 200 g) 30 cm laterally as fast as possible using a precision timer.¹² According to a previous research, an acceleration area of 10 cm was set on a table. The participants were instructed to move the plastic box over the end line as fast as possible using their right hand. This test was measured five times after two practice trials, and the best time was taken for further analysis.

The maximal joint angular velocity of knee extension was measured to represent movement velocity of the lower limbs.⁹ A gyroscope (45 mm×25 mm×15 mm; Micro Stone Inc., Saku, Japan) and a 2-kg ankle weight were fixed on the distal position of the tibia. The participants were asked to sit in a chair with their knees and hips at 90 degrees of flexion and to keep their trunk upright. The participants were instructed to extend their knees as quickly as possible. They performed the task five times consecutively.

Measurements of muscle strength

Isometric quadriceps strength was measured with a handheld dynamometer.²⁰ The measurement was performed with the participants in a sitting position, with the hips and knees in approximately 90 degrees of flexion.

Statistical analysis

All variables were expressed as mean and SDs. Differences in baseline characteristics including demographic information between the groups were evaluated using the Student *t* test. Pearson's correlation coefficient was conducted to demonstrate the correlation between gait ability and movement velocity. A repeated-measures ANCOVA was performed to examine the main effects of time and interaction between the groups and time. In this analysis, gait ability, movement velocity, and muscle strength measurement values of each time point were included as levels of the within-subject "time" factor. Training and control groups were included as levels of the within-subject "group" factors. Baseline measurements were included as covariates. Differences between preintervention and each time point were examined using post-hoc analysis (Bonferroni test). Effect sizes were measured using partial η^2 . In a previous study, partial η^2 of 0.01, 0.06, and 0.14 may be considered the boundaries for small, medium, and large effects, respectively.²¹ For all analyses, the level of statistical significance was set at $p < 0.05$ (two-tailed). Statistical analysis was performed according to the standard methods using SPSS version 24.0 (IBM Japan, Ltd., Tokyo, Japan).

Results

Flowchart of participant recruitment and retention in this study is shown in Figure 2. From a pool of 94 participants, 70 adults were eligible to participate, with 24 participants dropping out. Seventeen participants from the movement velocity training group dropped out from the study due to declined ($n=4$), health conditions unrelated to the study ($n=9$), discharged from facility ($n=3$), and questionable data ($n=1$). A total of 12 participants dropped out from the control group due to declined ($n=1$), health conditions unrelated to the study ($n=7$), and discharged from facility ($n=4$). None of the participants complained of upper limb pain or showed obvious distress due to the training protocol.

Participants' baseline characteristics are presented in Table 1. No significant difference was found in the characteristics between the two groups. Moreover, the correlation between gait ability and movement velocity is shown in Table 2. A significant correlation was found between gait ability and movement velocity, and the upper and lower limbs of movement velocity.

Gait ability

To control for baseline differences, repeated-measures ANCOVA was adjusted for baseline values. A significant time-group interaction was found ($p=0.001$, partial $\eta^2=0.172$) for maximum gait speed (Table 3). Bonferroni post-hoc test showed a significant increase in gait speed between pre-intervention and 10 weeks after intervention in the movement velocity training group. No significant time-group interaction was found for usual gait speed and TUG ($p=0.076$, $p=0.563$).

Movement velocity and muscle strength

To control for baseline differences, repeated-measures ANCOVA was adjusted for baseline values. A significant time-group interaction was observed ($p=0.02$, partial $\eta^2=0.126$) for movement velocity of the upper limbs (Table 4). Bonferroni post-hoc test showed a significant increase in movement velocity of the upper limbs between pre-intervention and 4 weeks ($p=0.018$), 8 weeks ($p=0.001$), and 10 weeks ($p=0.000$) after intervention in the movement velocity training group. No significant time-group interaction was found for movement velocity of the lower limbs and quadriceps strength ($p=0.772$, $p=0.629$).

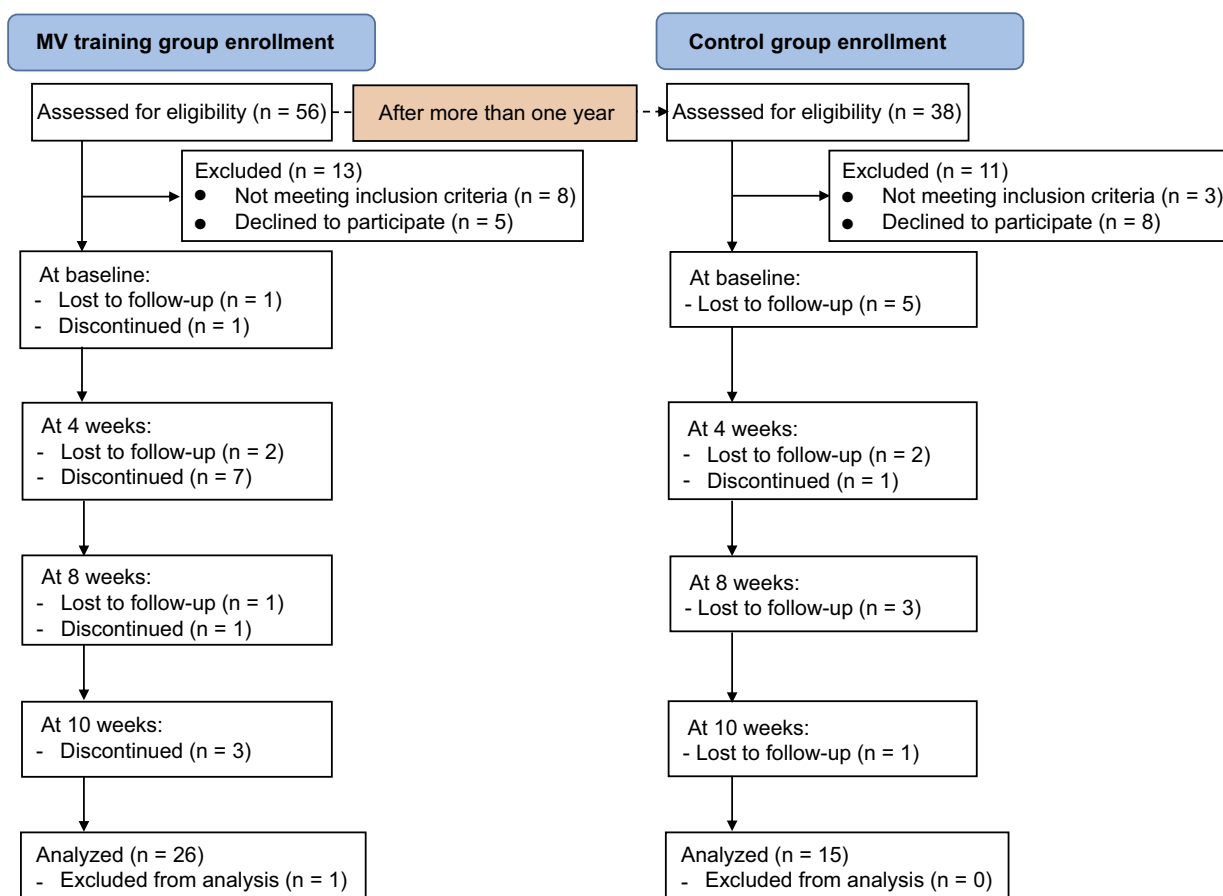


Figure 2 Flow diagram of subjects through the study.

Table 1. Characteristics of the study population

Characteristic	Movement velocity training (n = 26)		Control (n = 15)		p value
	Value	Range	Value	Range	
Age (years)	85.9 ± 6.9	69 – 99	82.7 ± 7.5	65 – 92	0.171
Female, n (%)	23 (88.5)		13 (86.7)		
Height (cm)	145.8 ± 10.3	126.0 – 168.0	148.5 ± 10.0	130.0 – 168.0	0.426
Weight (kg)	42.9 ± 7.4	30.8 – 60.0	45.3 ± 5.5	35.0 – 57.0	0.283
Body mass index (kg/m ²)	20.1 ± 2.7	16.4 – 26.7	20.7 ± 2.8	16.3 – 25.7	0.560

Note: Mean ± Standard Deviation (SD).

Table 2. Correlation of gait ability and movement velocity of the upper and lower limbs

	Movement velocity of the lower limbs		Maximum gait speed		Usual gait speed		Timed up and go test	
	r	p -value	r	p -value	r	p -value	r	p -value
Movement velocity of the upper limbs (n = 41)	0.70	0.00	0.53	0.00	0.33	0.04	−0.39	0.01
Movement velocity of the lower limbs (n = 32)			0.78	0.00	0.66	0.00	−0.63	0.00
Maximum gait speed (n = 41)					0.88	0.00	−0.69	0.00
Usual gait speed (n = 41)							−0.76	0.00

Table 3. Descriptive statistics and group comparisons of gait ability

	Pre-intervention	4 weeks	8 weeks	10 weeks
Maximum gait speed* (m/s)				
Movement velocity training (n = 26)	0.84 ± 0.25 [‡]	0.82 ± 0.26	0.88 ± 0.32	0.95 ± 0.36 [†]
Control (n = 15)	1.06 ± 0.29	1.08 ± 0.29	1.09 ± 0.31	1.11 ± 0.31
Usual gait speed (m/s)				
Movement velocity training (n = 26)	0.67 ± 0.18 [‡]	0.67 ± 0.19	0.69 ± 0.20	0.74 ± 0.23
Control (n = 15)	0.83 ± 0.26	0.81 ± 0.26	0.84 ± 0.26	0.82 ± 0.24
TUG (s)				
Movement velocity training (n = 26)	21.7 ± 9.8	21.2 ± 8.9	20.5 ± 8.4	19.0 ± 9.6
Control (n = 15)	16.8 ± 7.6	17.3 ± 7.8	15.6 ± 6.8	15.7 ± 6.5

Notes: *Group × time interaction ($p < 0.05$).

[†]Significant within-group differences from baseline ($p < 0.05$) (Bonferroni adjusted).

[‡]Significant between-group differences at baseline ($p < 0.05$).

Abbreviation: TUG, timed up and go.

Discussion

The purpose of this study was to assess the beneficial effects of movement velocity training of the upper limbs on gait ability in older adults in geriatric health service facilities. The movement velocity training of the upper limbs showed a significant improvement in maximum gait speed. In addition, the difference in maximum gait speed between preintervention and 10 weeks after intervention was 0.11 m/s. The clinically significant difference in gait speed is generally accepted at 0.1 m/s or more.^{22,23} Therefore, this study suggests that movement velocity training of the upper limbs is an effective intervention to improve mobility in older adults.

There are two possible reasons why gait speed improved significantly in the training group compared with that in the control group. First, gait speed improvement may be due to a change in arm swing during gait. Elftman reported that arm

swing motion helps stabilize rotational body motion during gait.²⁴ Furthermore, a previous study indicates that arm swing during gait may facilitate lower limb muscle activation via neural coupling.²⁵ Arm swing training also significantly improves the gait speed of stroke patients compared with that of the control group.²⁶ In addition, a previous study also reported that an increase in arm swing speed positively changes the gait parameter, particularly gait speed.²⁷ The movement velocity of the upper limbs was significantly improved by the movement velocity training of the upper limbs, leading to an improvement in gait speed.

Second, trunk muscle strength may be improved by training. Trunk muscle strength contributes to stability during gait,²⁸ and trunk muscle strength training was reported to be effective at improving gait speed in community-dwelling older adults.²⁹ The muscle activation required for the development of muscle strength of the back and abdominal can be

Table 4. Descriptive statistics and group comparisons of movement velocity and muscle strength

	Pre-intervention	4 weeks	8 weeks	10 weeks
Movement velocity of the upper limbs* (m/s)				
Movement velocity training (n = 17)	1.92 ± 0.51 [‡]	2.13 ± 0.54 [†]	2.33 ± 0.66 [†]	2.43 ± 0.67 [†]
Control (n = 15)	2.75 ± 0.83	2.82 ± 0.75	2.66 ± 0.77	2.79 ± 0.71
Movement velocity of the lower limbs (deg/s)				
Movement velocity training (n = 17)	255.6 ± 79.3 [‡]	290.5 ± 87.9	282.2 ± 87.4	289.5 ± 87.6
Control (n = 15)	336.7 ± 73.1	322.2 ± 55.7	338.6 ± 64.9	339.8 ± 56.2
Quadriceps strength (kg)				
Movement velocity training (n = 17)	10.9 ± 4.0	10.3 ± 4.3	10.6 ± 3.4	10.8 ± 3.2
Control (n = 15)	13.4 ± 4.4	13.1 ± 4.3	13.9 ± 5.5	12.5 ± 4.5

Notes: *Group × time interaction ($p < 0.05$).

[†]Significant within-group differences from baseline ($p < 0.05$) (Bonferroni adjusted).

[‡]Significant between-group differences at baseline ($p < 0.05$).

achieved during maximum contraction of shoulder extension and horizontal extension muscles.³⁰ Trunk flexion muscles are more active when moving the upper limbs as fast as possible compared with when moving slowly.³¹ Based on these previous findings, the movement of shoulder joint extension and horizontal extension as fast as possible may be sufficient to improve trunk muscle strength.

Movement velocity training of the upper limbs has factors of both motion direction (extension and horizontal extension of the shoulder joint) and high velocity. Therefore, we supposed that trunk function was improved by training, which led to improvement in gait speed.

Maximum gait speed showed a significant improvement in the training group, but usual gait speed had no significant improvement. Arai et al⁹ reported that maximum gait speed, but not usual gait speed, is significantly correlated with knee extension movement velocity. Sayers et al³² reported that maximum gait speed improves significantly by movement velocity training. However, they did not find a difference in the change of usual gait speed.³² Movement velocity is a more important factor for maximum gait speed compared with usual gait speed, and the effect of movement velocity training influences only maximum gait speed. Therefore, only maximum gait speed improved in this study.

This study has several limitations. First, the first limitation was the absence of randomization. The number of participants was quite small, and the participants were difficult to divide into two groups at the same time in the same facility. Second, the maximum and usual gait speeds before the intervention of the training group were significantly slower than those of the control group. The difference in trainability between the training and control groups may have influenced the results. Third, the majority of participants were female (male to female ratio was 1:9). Previous studies reported that the characteristics of movement velocity differ depending on gender.³³ The effect of gait ability improvement may differ between men and women even in movement velocity training. Finally, we could not elucidate the mechanism by which maximum gait speed was improved by movement velocity training of the upper limbs. Further research is required to investigate factors that increased gait speed.

Conclusion

Movement velocity training of the upper limbs showed significant and clinically relevant improvements in maximum gait speed. The gait function is important not only for healthy older adults,³⁴ but also for older adults with poor

physical function, such as the patients who have stroke³⁵ or orthopedic disease.³⁶ Moreover, gait function affects the prognosis more than the cardiac function in older adults with chronic heart failure.³⁷ The movement velocity training of upper limbs is low-load training in a seated position. Therefore, this training is a useful intervention and can be safely performed in a wide range of participants.

Acknowledgment

We thank Mr. Ikushima, Ms. Noguchi, Mr. Kano, Mr. Hamasaki, Mr. Higano, and Ms. Sakamoto for their help with recruitment of participants for this study.

Disclosure

The authors report no conflicts of interest in this work.

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