

# Repeated Use of 6-min Walk Test with Immediate Knowledge of Results for Walking Capacity in Chronic Stroke: Clinical Trial of Fast versus Slow Walkers

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*Aim:* This study aimed to determine the effects of repeated use of the 6-minute walk test (6MWT) with immediate knowledge of results (KR) on the walking capacity by comparing fast and slow walkers in patients with chronic hemiparesis. *Methods:* Twenty-five subjects were allocated to 2 groups depending on their walking speed<sup>1</sup>: Group 1 (fast walkers,  $n_1 = 11$ ): greater than equal to .8 m/s and<sup>2</sup> Group 2 (slow walkers,  $n_2 = 14$ ): less than .8 m/s. All subjects underwent the 6MWT once a day, 5 days a week, for 4 weeks (a total of 20 sessions). The 6MWT was performed on a 30-m path with immediate KR; subjects informed the time taken to walk each 30-m path. Outcome measures included the 6MWT and 10-meter walk test (10MWT). Measurements were taken before and after 4 weeks. Results of within-group comparisons showed significant improvements in the 10MWT and 6MWT for both groups pre- and post-test ( $P < .05$ ). Furthermore, in between-group comparison, results of Group 1 differences were greater between pre- and post-test in the 10MWT and 6MWT values as compared to Group 2 ( $P < .05$ ). These findings indicate that repeated use of the 6MWT with immediate KR may be beneficial to enhance walking capacity in patients with chronic stroke, with more favorable changes in better poststroke walking speed.

**Key Words:** Knowledge of results—six-min walk test—stroke—walking

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## Introduction

In patients with stroke, functional disability results from motor and sensory paralysis caused by neurological damage, including spasticity, decrease in muscle strength, impaired sensory perception, and motor coordination deficits.<sup>1</sup> This limits a successful return to premorbid life and community reintegration. Most people with poststroke hemiparesis often complain of difficulty in maintaining a

normal walking speed because of problems associated with optimal spatiotemporal regulation.<sup>2</sup> This is one of the major factors that make normal planning and execution of daily activities difficult along with other perceptible and cognitive disorders.

Walking is one of the most important activities needed to maintain independence in daily life, and is considered a prerequisite for numerous productive activities.<sup>3</sup> In particular, ambulation is vital for community reintegration in patients with poststroke hemiparesis.<sup>4</sup> Clinically, the 6-Minute Walk Test (6MWT) is a known beneficial tool to evaluate walking endurance in patients with poststroke hemiparesis.<sup>5</sup> It provides a criterion to judge whether people can walk independently in the community environment.<sup>6-8</sup> In general, walking capacity after stroke influences the outcome of the 6MWT,<sup>9</sup> and may be potentially meaningful to demonstrate clinical benefit from training,<sup>10</sup> which depends on levels of stroke severity.

A feedback mechanism offers a person visual and auditory information in response to a functional performance, which means that patients can be aware of a process and the results of their own performance. This has been

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adopted by physical and occupational therapists in rehabilitation settings to encourage the process of learning new skills.<sup>11</sup> Knowledge of results (KR) expresses external information about the results of a performance verbally after the completion of actions performed with a specific goal.<sup>12</sup> In general, patients with poststroke hemiparesis find it difficult to accept their performance and quality levels when they begin learning new skills. Therefore, KR information may facilitate the performance and learning process by offering opportunities that lead to increased interests in activities by immediately notifying the outcome of performance. If learners cannot accept information about their own errors or performance levels, then the process of leaning through repeated practice would be less effective.<sup>11</sup> Therefore, external feedback in the form of KR should be incorporated as an essential element in stroke rehabilitation.

Numerous conventional treatments to restore normal walking following stroke have been demonstrated to clinicians, including neurophysiological approaches, orthopedic techniques, and functional training. However, clinical superiority of these treatments has not been proved by previous research on walking recovery in patients with poststroke hemiparesis.<sup>12</sup> Based on motor learning principles, learning process requires the practice of repeating meaningful activities by patients, focusing on active participation to improve walking ability and life pattern.<sup>13,14</sup> This concept supports the use of progressive resistive exercise,<sup>15</sup> training by walking on the treadmill,<sup>16</sup> and task-oriented training for patients with poststroke hemiparesis.<sup>17</sup> Also, it provides a theoretical framework for the possible effects of repeated 6MWT as walking training.<sup>18</sup>

Previous studies have reported that repeated use of the 6MWT may improve walking function in deconditioned elderly patients<sup>19</sup> or in patients with cardiopulmonary diseases.<sup>20-22</sup> However, to the best of our knowledge, little attention has been paid to analyze the effects of the 6MWT as a tool to promote walking function of patients with poststroke hemiparesis. Liu et al<sup>23</sup> was unable to prove the positive effects of the 6MWT in patients with poststroke hemiparesis, whereas Sim et al<sup>18</sup> reported that the repeated use of the 6MWT may be more effective in improving walking function after stroke by integrating KR. These studies analyzed immediate rather than long-term effects of repeatedly using the 6MWT. There is insufficient evidence regarding the effects of long-term use of the 6MWT. Thus, the present study aimed to identify the effects of repeated use of the 6MWT with immediate KR on the walking capacity via comparison of fast versus slow walkers in patients with poststroke hemiparesis. We postulated that repeated use of the 6MWT with immediate KR will enhance the walking capacity of poststroke hemiparesis, and this improvement would vary depending on the walking speed of patients after stroke.

## Methods

### Subjects

Thirty-two patients with a history of chronic stroke volunteered for this study. Inclusion criteria were as follows:<sup>1</sup> stroke more than 6 months ago,<sup>2</sup> ability to walk independently for 6 minutes with or without walking aids,<sup>3</sup> absence of orthopedic, cardiopulmonary, and other neurological diseases, and<sup>4</sup> absence of cognitive impairment (>24 points in the Korean version of the Mini-Mental State Examination [MMSE-K]).<sup>24</sup> Based on classification of walking speeds in a study by Perry et al<sup>25</sup> the subjects were divided into 2 groups<sup>1</sup>: fast walker group: more than equal to .8 m/s ( $n_1 = 11$ ) (community ambulation) and<sup>2</sup> slow walker group: less than .8 m/s ( $n_2 = 14$ ) (limited community ambulation or domestic ambulation).

Sixty-four patients with poststroke hemiparesis were initially screened. However, 31 subjects were excluded due to cognitive impairments and refusal to participate in the study; thus, the remaining 33 patients were allocated to the either Group 1 (fast walkers) ( $n = 16$ ) or Group 2 (slow walkers) ( $n = 17$ ). During the study, 11 subjects (Fast Walker Group: 5, Slow Walker Group: 3) were excluded due to hospital discharge and refusal to participate further. Consequently, the final analysis included data of 25 subjects (Fig. 1). Before the study began, information regarding the experiment and its safety aspects was provided, and all subjects submitted signed informed consent forms.

### Outcome Measures

The 10-meter walk test (10MWT) is a common tool to assess walking speeds in clinical settings.<sup>26</sup> The 10MWT was conducted in a straight 14 m route, and subjects were instructed to walk at a speed comfortable to them. To avoid the effects of acceleration and deceleration on the walking speeds, measurements were taken in the middle of the 10 m route by excluding the first and last 2-m intervals. Time was recorded using a stopwatch (I-Phone, Apple). The data obtained after 3 trials was averaged. Test reliability measured with test-retest correlation for the 10MWT was  $r = .87$  for patients with poststroke hemiparesis.<sup>27</sup>

The 6MWT was performed on a straight 30-m route with marks indicating intervals every 1 m. The start and end points of 30 m were indicated by 2 bars, and the subjects were instructed to walk between the bars for 6 minutes. The protocol for the 6MWT followed guidelines of the American Thoracic Society (ATS).<sup>28</sup> Subjects were encouraged to walk as far as possible for 6 minutes, with feedback given only during measurement. The distances walked by the subjects were recorded. The 6MWT has been reported to be highly reliable for clinical use (intraclass correlation coefficient = .98).<sup>23</sup>

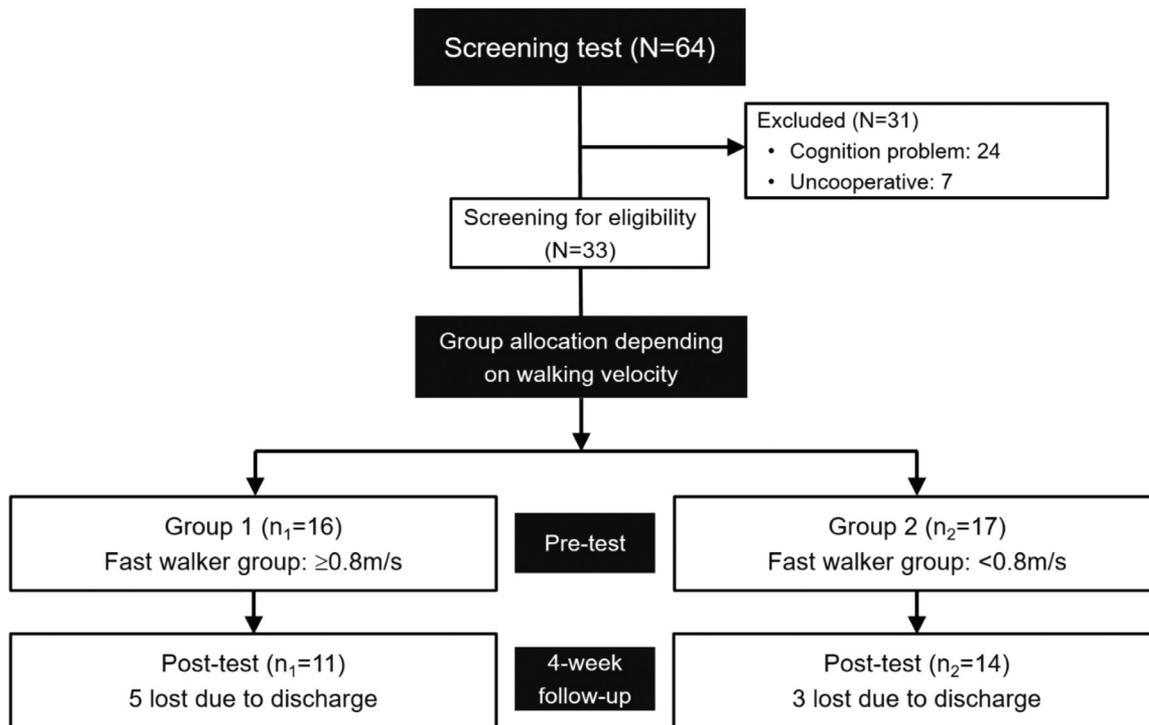


Figure 1. Flow chart of the study.

*Procedure*

Based on the initial walking speeds, all subjects performed the 6MWT with immediate KR once a day (a total of 20 sessions). All procedures for the 6MWT were according to the ATS<sup>28</sup> standard. The first author of present study explained the procedure at the beginning of the 6MWT, but no instructions were given to the subjects during the test. Subsequently, the walking speed was modified individually depending on the one’s condition. As suggested in a previous study,<sup>18</sup> immediate KR was done to inform the subjects of the time required to pass the 30 m distance. Data were collected was at baseline and after 4 weeks. Differences in values at baseline and each measurement period were recorded for further analysis.

*Data Analysis*

Statistical analysis was done using SPSS (Statistical Package for Social Science, Chicago) version 22.0. The data were expressed as means and standard deviations. The Kolmogorov-Smirnov test was used to determine normality of data, and values of the 10MWT and 6MWT collected from each group was normally distributed ( $P > .05$ ). To show evidence of homogeneity within the group, an independent *t* test was used to analyze the parametric data for general characteristics of both groups (eg age, onset duration, and MMSE-K score). In the 10MWT and 6MWT tests, within-group comparisons for both groups were analyzed using a paired *t* test, and between-group

comparisons for differences between pre- and post-test values was analyzed using an independent *t* test. Statistically significant levels were set at *P* less than .05.

**Results**

*General Characteristics of the Subjects*

Table 1 summarizes general characteristics of the subjects. There were no significant differences in age, onset duration, and MMSE-K scores ( $P > .05$ ).

*Within- and Between-group Comparisons of the 10MWT and 6MWT Values*

Table 2 represents the outcome of the 10MWT and 6MWT between pre- and post-test in Group 1 and 2. In within-group comparisons, the 10MWT and 6MWT values of both groups showed significant differences between pre- and post-test ( $P < .05$ ), and in the between-group comparison, the change values of 10MWT and 6MWT between pre- and post-test were significantly higher for Group 1 when compared to those of Group 2 ( $P < .05$ ).

**Discussion**

In stroke rehabilitation, current recommendations include providing sufficient opportunities for patients to walk independently thereby regaining walking skills in a self-selected way and establishing appropriate problem-solving strategies in real situations. This study analyzed

**Table 1.** General characteristics of the subjects

	Group 1 (n <sub>1</sub> = 11)	Group 2 (n <sub>2</sub> = 14)	<i>t</i>	<i>P</i>
Sex (male/female)	8/3	8/6	-.32	.76
Age (y)	54.73 ± 7.86	53.29 ± 7.95	.45	.66
Types of stroke (infarction/hemorrhage)	8/3	7/7	-.67	.52
Affected side (right/left)	8/3	6/8	-1.01	.32
Onset time (mo)	18.27 ± 6.72	17.86 ± 8.27	.14	.89
Use of walking aids (persons)	9/2	7/7	-1.68	.11
MMSE-K (scores)	26.18 ± 1.25	26.00 ± 1.67	.30	.77

Group 1: Fast walkers, speed ≥ .8 m/s.

Group 2: Slow walkers, speed < .8 m/s.

MMSE-K: Korean version of Mini-Mental State Examination.

the effects of repeatedly utilizing the 6MWT with immediate KR in patients with poststroke hemiparesis. We found that repeated use of the 6MWT with immediate KR improved the walking capacity of the patients with poststroke hemiparesis, with more favorable changes in better poststroke walking speed.

In general, sensorimotor and cognitive impairments after stroke are major factors that impede the walking ability during daily activities and consequently decrease self-efficacy in walking. Given that safety issues may be a major concern, patients have a tendency not to move actively or walk independently without support from others. Lack of physical activities decreases functional performance after stroke.<sup>29</sup> The 6MWT requires sustained body movements to maintain suitable walking patterns during relatively long periods, and provides immediate outcomes of the test. Therefore, it is recommended to increase patient activity levels and motivate them to walk.<sup>30</sup> Repetition of the 6MWT can also be used to encourage patients to walk. A study by Sim et al<sup>18</sup> established possible benefits related to walking despite its simplicity in patients with chronic stroke when immediate KR was incorporated into the 6MWT. In this study, instructions for immediate KR were given according to protocol.<sup>18</sup> Unlike previous studies that simply investigated the initial effects of repetitive 6MWT,<sup>18,23</sup> we performed the 6MWT every day for 4 weeks to identify long-term results of the 6MWT.

The results of this study indicate that repeated use of 6MWT may enhance walking in patients with poststroke hemiparesis. However, Liu et al<sup>23</sup> analyzed the effect of repetitive 6MWT poststroke, and concluded that there was insufficient evidence in clinical settings. The 6MWT has been commonly used to determine the walking endurance of patients with poststroke hemiparesis in clinical settings because of the ease of the process.<sup>8</sup> Procedures that require walking for 6 minutes produce fatigue, which is responsible for the lack of practice effects.<sup>23</sup> ATS<sup>28</sup> recommended rest intervals of more than 1-hour between the trials to avoid fatigue. As shown in this study, walking was improved by repeated use of the 6MWT; this may be associated with

compliance to the basic rules in the test. From our findings, a possible explanation for this is the integration of immediate KR into the 6MWT. It is difficult for patients with poststroke hemiparesis to recognize the process and outcome of functional performance without feedback-related information; hence, immediate KR is used to reinforce motor learning, particularly in early stages.<sup>10</sup> Other studies have reported an increase in the distance walked by healthy patients,<sup>19,31</sup> and patients with cardiopulmonary problems<sup>22,32</sup> during the 6MWT. These results may be crucial to support our findings, although these data were not collected from patients with poststroke hemiparesis.

In this study, subjects were classified into 2 groups depending on walking speeds, based on criteria provided by Perry et al<sup>25</sup> and identify whether the repeated use of the 6MWT was different between faster and slower walkers. As shown in this study, 10MWT scores improved across the groups after a 4-week period, indicating that improvement (.30 m/s) among fast walkers met the criteria for the minimal detectable change (.17 m/s)<sup>33</sup> and minimum clinically important difference (.16 m/s).<sup>34</sup> After the 4-week intervention, there was an improvement in the 6MWT across the groups, with improvement (96 m) in fast walkers who met the criteria for minimum clinically important difference (71 m).<sup>35</sup>

Improvement in the 10MWT and 6MWT appeared to be higher for faster than slower walkers. The 6MWT included walking in the straight route and turning 180°. Generally, slower walkers complained frequently about the difficulty in change of direction because of a fear of falling; therefore, their walking speed was often remarkably reduced during turning.<sup>8</sup> This was probably a reason for the lower values of the 6MWT in slow walkers after stroke. In addition, outcomes of the 6MWT varied across a range of performance levels. It is possible that most patients with chronic stroke show poor cardiovascular endurance. This makes it difficult to adjust walking and functional performance based on perceived physiologic response, which eventually influences the test.<sup>23</sup> After a stroke, walking capacity may be related to recovery of neuromuscular function and slower walkers may have

**Table 2.** Comparison of walking speed and distance between both groups over time and mean (95% CI) difference between between times

	Group 1 (n <sub>1</sub> = 11)			Group 2 (n <sub>2</sub> = 14)			Total (N = 25)		
	Pretest	Posttest	t*	Pretest	Posttest	t*	Pretest	Posttest	t*
Speed (10MWT, m/s)	1.01 ± .15	1.31 ± .23	-5.44	.40 ± .18	.51 ± .27	-4.58	.67 ± .35	.86 ± .47	-5.81
Distance (6MWT, m/s)	317.18 ± 58.18	413.18 ± 76.86	-5.87	127.86 ± 62.06	171.79 ± 80.87	-5.71	211.16 ± 112.68	278.00 ± 144.78	-6.86

Group 1: Fast walkers, speed ≥ .8 m/s.

Group 2: Slow walkers, speed < .8 m/s.

\*Within-group comparison between pre- and post-test values in each parameter.

†Between-group comparison of the change between pre- and post-test values in each parameter.

less voluntary control due to incomplete functional recovery of the neuromuscular system.

Although there are benefits in repeated use of the 6MWT, we acknowledge several limitations that can be improved in further studies. First, our sample was small, which limits generalization of our findings to the entire stroke population. Second, measurements were collected after 4 weeks; thus, our results cannot be described as long-term effects. Third, the improvement of walking capacity in this study may be task-specific effect; therefore, it could not assure possible effects in the whole aspects of function. Finally, the focus of this study was to identify the effects of repeatedly using the 6MWT with immediate KR in terms of clinical walking function rather than a kinematic analysis of walking. Therefore, this study did not summarize quantitative data regarding the walking motion. Further studies with larger sample sizes and longer durations of follow-ups are recommended.

### Conclusion

Recovery of walking function in stroke rehabilitation is one of the most important goals to maintain functional independence. The current consensus is that intensive, repeated walking is advantageous to regain walking skills in daily life, while facilitating the process of motor learning with feedback information related to the performance. Based on this concept, this study was performed to determine the effects of repeatedly using the 6MWT with immediate KR in patients with poststroke hemiparesis by comparing its effects in fast and slow walkers. Our findings indicate that the repeated use of the 6MWT with immediate KR enhanced the walking capacity of patients with poststroke hemiparesis, and this improvement was greater for patients showing better walking speed after stroke. Further studies to substantiate our results are recommended.

### Declaration of Competing Interest

The authors have no conflicts of interest to declare.

### Supplementary Materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jstrokecerebrovasdis.2019.104337.

### References

1. Stevens JA, Stoykov MEP. Using motor imagery in the rehabilitation of hemiparesis. *Arch Phys Med Rehabil* 2003;84:1090-1092.
2. Yang YR, Wang RY, Lin KH, et al. Task-oriented progressive resistance strength training improves muscle strength and functional performance in individuals with stroke. *Clin Rehabil* 2006;20:860-870.

3. Ada L, Dean CM, Lindley R, et al. Improving community ambulation after stroke: the AMBULATE trial. *BMC Neurol* 2009;9:8.
4. Lord SE, McPherson K, McNaughton HK, et al. Community ambulation after stroke: how important and obtainable is it and what measures appear predictive? *Arch Phys Med Rehabil* 2004;85:234-239.
5. Guyatt GH, Sullivan MJ, Thompson PJ, et al. The 6-minute walk: a new measure of exercise capacity in patients with chronic heart failure. *Can Med Assoc J* 1985;132:919.
6. Dean CM, Richards CL, Malouin F, et al. Walking speed over 10 metres overestimates locomotor capacity after stroke. *Clin Rehabil* 2001;15:415-421.
7. Carvalho C, Sunnerhagen KS, Willén C. Walking speed and distance in different environments of subjects in the later stage post-stroke. *Physiother Theory Pract* 2010;26:519-527.
8. Lam T, Luttmann K. Turning capacity in ambulatory individuals poststroke. *Am J Phys Med Rehabil* 2009;88:873-883.
9. Schmid A, Duncan PW, Studenski S, et al. Improvements in speed-based gait classifications are meaningful. *Stroke* 2007;38:2096-2100.
10. Schmidt RA. Motor learning principles for physical therapy. In: *Contemp Manag Mot Control Probl Proc II STEP Conference*; 1991. Alex 49-63.
11. Schmidt RA, Lee TD. Motor control and learning. A behavioral emphasis. Champaign, IL: Human Kinetics; 1999.
12. Pollock A, Baer G, Langhorne P, Pomeroy V. Physiotherapy treatment approaches for the recovery of postural control and lower limb function following stroke: a systematic review. *Clin Rehabil* 2007;21:395-410.
13. Kosak MC, Reding MJ. Comparison of partial body weight-supported treadmill gait training versus aggressive bracing assisted walking post stroke. *Neurorehabil Neural Repair* 2000;14:13-19.
14. Visintin M, Barbeau H, Korner-Bitensky N, et al. A new approach to retrain gait in stroke patients through body weight support and treadmill stimulation. *Stroke* 1998;29:1122-1128.
15. Flansbjerg UB, Miller M, Downham D, et al. Progressive resistance training after stroke: effects on muscle strength, muscle tone, gait performance and perceived participation. *J Rehabil Med* 2008;40:42-48.
16. Dobkin BH. Strategies for stroke rehabilitation. *Lancet Neurol* 2004;3:528-536.
17. Canning CG, Ada L, Paul SS. Is automaticity of walking regained after stroke? *Disabil Rehabil* 2006;28:97-102.
18. Sim SM, Oh DW. Use of the 6-minute walk test as gait therapy for hemiplegic patients: possibility of practice effect by providing knowledge of result. *Korean J Health Promot* 2011;11:42-47.
19. Kervio G, Carre F, Ville NS. Reliability and intensity of the six-minute walk test in healthy elderly subjects. *Med Sci Sports Exerc* 2003;35:169-174.
20. Bellet RN, Francis RL, Jacob JS, et al. Repeated six-minute walk tests for outcome measurement and exercise prescription in outpatient cardiac rehabilitation: a longitudinal study. *Arch Phys Med Rehabil* 2011;92:1388-1394.
21. Jenkins S, Cecins NM. Six-minute walk test in pulmonary rehabilitation: do all patients need a practice test? *Respirology* 2010;15:1192-1196.
22. Sciurba F, Criner GJ, Lee SM, et al. Six-minute walk distance in chronic obstructive pulmonary disease: reproducibility and effect of walking course layout and length. *Am J Respir Crit Care Med* 2003;167:1522-1527.
23. Liu J, Drutz C, Kumar R, et al. Use of the six-minute walk test poststroke: is there a practice effect? *Arch Phys Med Rehabil* 2008;89:1686-1692.
24. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state": a practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res* 1975;12:189-198.
25. Perry J, Garrett M, Gronley JK, et al. Classification of walking handicap in the stroke population. *Stroke* 1995;26:982-989.
26. Cleland BT, Arshad H, Madhavan S. Concurrent validity of the GAITRite electronic walkway and the 10-m walk test for measurement of walking speed after stroke. *Gait Posture* 2019;68:458-460.
27. Green J, Forster A, Young J. Reliability of gait speed measured by a timed walking test in patients one year after stroke. *Clin Rehabil* 2002;16:306-314.
28. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS statement: guidelines for the six-minute walk test. *Am J Respir Crit Care Med* 2002;166:111-117.
29. Lord SE, Weatherall M, Rochester L. Community ambulation in older adults: which internal characteristics are important? *Arch Phys Med Rehabil* 2010;91:378-383.
30. Wu D, Wang L, Teng W, et al. Correlation of post-stroke fatigue with glucose, homocysteine and functional disability. *Acta Neurol Scand* 2015;131:400-404.
31. Wu G, Sanderson B, Bittner V. The 6-minute walk test: how important is the learning effect? *Am Heart J* 2003;146:129-133.
32. Hamilton DM, Haennel RG. Validity and reliability of the 6-minute walk test in a cardiac rehabilitation population. *J Cardiopulm Rehabil Prev* 2000;20:156-164.
33. Evans MD, Goldie PA, Hill KD. Systematic and random error in repeated measurements of temporal and distance parameters of gait after stroke. *Arch Phys Med Rehabil* 1997;78:725-729.
34. Perera S, Mody SH, Woodman RC, et al. Meaningful change and responsiveness in common physical performance measures in older adults. *J Am Geriatr Soc* 2006;54:743-749.
35. Fulk GD, He YH. Minimal clinically important difference of the 6-minute walk test in people with stroke. *J Neurol Phys Ther* 2018;42:235-240.