

Dual-Task Exercise Improves Walking Ability in Chronic Stroke: A Randomized Controlled Trial

Yea-Ru Yang, PT, PhD, Ray-Yau Wang, PT, PhD, Yu-Chung Chen, PT, MS, Mu-Jung Kao, MD

ABSTRACT. Yang YR, Wang RY, Chen YC, Kao MJ. Dual-task exercise improves walking ability in chronic stroke: a randomized controlled trial. *Arch Phys Med Rehabil* 2007; 88:1236-40.

Objective: To examine the effectiveness of a dual-task-based exercise program on walking ability in subjects with chronic stroke.

Design: Single-blind randomized controlled trial.

Setting: General community.

Participants: Twenty-five subjects with chronic stroke who were at least limited community ambulatory subjects (a minimum gait velocity, 58cm/s).

Interventions: Participants were randomized into a control group (n=12) or experimental group (n=13). Subjects in the control group did not receive any rehabilitation training. Subjects in the experimental group underwent a 4-week ball exercise program.

Main Outcome Measures: Gait performance was measured under single task (preferred walking) and tray-carrying task. Gait parameters of interest were walking speed, cadence, stride time, stride length, and temporal symmetry index.

Results: The experimental group showed significant improvement in all selected gait measures except for temporal symmetry index under both task conditions. In the control group, there were no significant changes over the 4-week period for all selected measures. There was a significant difference between groups for all selected gait variables except for temporal symmetry index under both task conditions.

Conclusions: The dual-task-based exercise program is feasible and beneficial for improving walking ability in subjects with chronic stroke.

Key Words: Cerebrovascular accident; Exercise; Rehabilitation; Walking.

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THE ABILITY TO WALK independently is a prerequisite for many daily activities. On discharge from rehabilitation programs, 60% to 80% of people poststroke can walk independently.^{1,2} Although gait restoration has long been recognized as a key goal in stroke rehabilitation, this emphasis has been extended to include the attainment of community ambulation in recent years. It has been reported that only a small proportion can walk with sufficient ability to function effectively within the community.^{3,4} Many people returning home after stroke rehabilitation walk at average speeds that are insufficient to cross the street safely or even to walk safely in the community.⁵⁻⁷ It is important to identify treatment approaches that maximize community ambulation.

Various approaches to stroke rehabilitation have been studied to improve the walking ability of people with hemiparesis.⁸⁻¹³ Improvements in walking ability provide people with opportunities to participate more easily in the community. It has been suggested that walking speed may be an appropriate primary endpoint in clinical trials for interventions to improve community mobility.⁴ However, it is not sufficient as a single measure of community ambulation function. Dual-task interference during ambulation is also an important factor. Lord and Rochester¹⁴ suggested that the development of clinical tests that incorporate dual-task paradigms as part of assessment may prove helpful in reflecting the broader dimensions of community ambulation. Our recent results¹⁵ have also suggested that rehabilitation after a stroke should involve the evaluation of the dual-task gait assessment. To our knowledge, no study has used the dual-task assessment as one of the outcome measures to evaluate the effectiveness of treatment approaches. Our present study was therefore designed to evaluate the effectiveness of a training program on dual-task-related gait performance in persons living with a chronic stroke in the community.

We developed a ball exercise program based on a dual-task concept. This exercise program was designed to challenge walking by manipulating either 1 or 2 balls concurrently. This dual-task-based ball exercise program was structured to improve walking ability for executing a dual task. The purpose of the present study was to examine the effectiveness of a dual-task-based exercise program on walking ability in subjects with chronic stroke.

METHODS

Participants

Subjects were recruited from community groups. The age, sex, paretic side, and onset time of hemiparesis were obtained from patient interviews and confirmed via medical records review. The inclusion criteria were (1) hemiparetic from a single stroke occurring at least a year earlier, (2) limited (gait velocity between 58 and 80cm/s) or full community ambulatory ability (minimum gait velocity of 80cm/s) by Perry et al's classification system,⁶ (3) not presently receiving any rehabilitation services, (4) able to walk 10m independently without an assistive device, (5) functional use of the involved upper extremity, (6) stable medical condition to allow participation in the testing protocol and intervention, and (7) an ability to

From the Faculty & Institute of Physical Therapy, National Yang-Ming University, Taipei, Taiwan (Yang, Wang); Section of Physical Therapy (Yang), Department of Education and Research (Wang), and Department of Physical Medicine and Rehabilitation (Kao), Taipei City Hospital, Taipei, Taiwan; and Division of Physical Therapy, Department of Physical Medicine and Rehabilitation, Cheng Hsin Rehabilitation Medical Center, Taipei, Taiwan (Chen).

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Reprint requests to Yea-Ru Yang, PT, PhD, Faculty & Institute of Physical Therapy, National Yang-Ming University, 155, Sec 2, Li-Nong St., Shih-Pai, Taipei, Taiwan, e-mail: yryang@ym.edu.tw.

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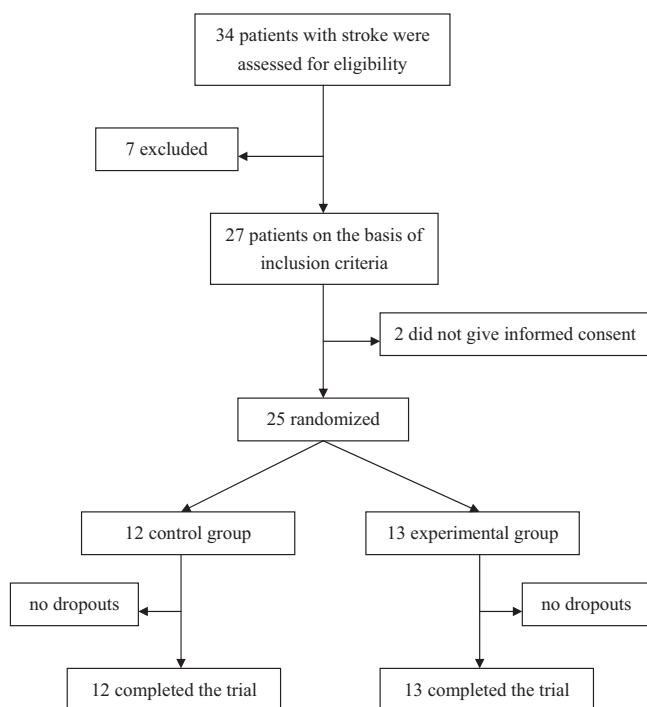


Fig 1. Flow diagram of the study.

understand instructions and follow commands. The exclusion criteria were (1) patient with any comorbidity or disability other than stroke that would preclude gait training, (2) any uncontrolled health condition for which exercise is contraindicated, and (3) any neurologic or orthopedic diseases that might interfere with the study.

Study Protocol

The study protocol was reviewed and approved by the institutional review board. Before data collection, the purposes and procedures were fully explained, and informed consent was obtained from each participant. Thirty-four subjects were identified as potential participants for this study. Seven were excluded because they failed to meet the inclusion criteria (fig 1). Two people did not sign an informed consent form. Twenty-five subjects signed an informed consent form before participating in the study. Participants were randomized to the control group or experimental group by an independent person who picked 1 of the sealed envelopes 30 minutes before the start of the intervention. All subjects were evaluated before the commencement of training (pretraining) and at the end of the 4-week training period (posttraining). Each subject was evaluated individually and tested following a standard protocol. Subjects were tested under the control single-task condition and under the dual-task condition. The 12 subjects in the control group did not receive any rehabilitation training. The remaining 13 subjects in the experimental group received ball exercise training.

Measurements

Subjects were evaluated by a physical therapist who was not involved in the training program and did not know about the subject's group assignment. For each subject, the gait performance was measured in 2 conditions: (1) preferred walking (single task) and (2) walking carrying a tray with glasses

(tray-carrying task). The instructions for each test condition were as follows: (1) "Walk with your comfortable speed right to the end of the walkway" and (2) "Walk with your comfortable speed right to the end of the walkway carrying this tray and glasses in front of you with both hands." For the tray-carrying task, subjects have to keep the empty glasses (height, 15cm; base diameter, 6cm) on the tray without any dropping otherwise the trial would be considered as failed. The trial order was randomized to compensate for the effects of practice and fatigue. To obtain representative samples, each test condition was repeated 3 times successfully, and the mean of the 3 successful trials was used for further data analysis.

Gait was measured by using GAITRite,^a an instrumented walkway. The GAITRite system provided temporal (time) and spatial (distance) gait parameters via an electronic walkway connected to the serial port of a personal computer. The standard GAITRite walkway contained 6 sensor pads encapsulated in a roll-up carpet with an active area of 3.66m long and 0.61m wide. The validity and reliability of the GAITRite system has been well established.^{16,17} Subjects were asked to walk at their comfortable speed without an assistive device through a 10-m hallway. The GAITRite walkway was placed in the middle of the 10-m hallway to eliminate the effect of initiating or stopping walking.

The temporospatial parameters recorded were as follows: speed (in cm/s), cadence (in steps/min), stride time (in seconds), stride length (in centimeters), affected single-limb support (percentage of gait cycle), and unaffected single-limb support (percentage of gait cycle). Single-limb support was used only to calculate the temporal symmetry index. The temporal symmetry index was calculated by using the following formula:

unaffected single limb support (% of gait cycle)/affected single limb support (% of gait cycle).¹⁸

Interventions

Subjects in the experimental group participated in 30 minutes of a ball exercise program 3 times a week for 4 weeks. The training program was based on a dual-task concept; subjects walked while manipulating either 1 or 2 balls. The balls used in this study were therapy balls with 45-, 55-, 85-, and 95-cm diameters and a basketball. The training program included (1) walking while holding 1 or 2 balls on both hands, (2) walking



Fig 2. The starting position of kicking a basketball.

Table 1: Baseline Demographic Characteristics of the Control and Experimental Groups

Variables	Control (n=12)	Experimental (n=13)	P
Age (y)	59.17±11.98 (45–80)	59.46±11.83 (47–76)	.95
Years poststroke	4.68±7.40 (1–28)	4.08±3.13 (1.1–9.5)	.79
Sex			
Male	7 (58.33)	7 (53.85)	1.00
Female	5 (41.67)	6 (46.15)	
Hemiparetic side			
Right	6 (50.00)	10 (76.92)	.16
Left	6 (50.00)	3 (23.08)	

NOTE. Values are mean ± SD (range) or frequency (percentage).

to match the rhythm of bouncing 1 ball with 1 hand or both hands, (3) walking while holding 1 ball on 1 hand and concurrently bouncing another ball with the other hand, (4) walking in time while kicking a basketball (the basketball was put into a net, and the net was held by the subject) (fig 2), (5) walking while holding 1 ball and concurrently kicking another basketball within a net, (6) walking while bouncing 1 ball and concurrently kicking another basketball within a net, and (7) walking while reciprocally bouncing 1 ball with both hands. Variable practice for the walking condition involved walking forward, walking backward, walking on a circular route, and walking on an S-shaped route. The subject was challenged with increasingly difficult tasks.

Data Analysis

Information from all subjects was entered into a computerized database and analyzed by using the SPSS statistical package.^b Descriptive statistics were calculated for the clinical characteristics of each group. To compare the baseline demographic characteristics and the pretraining variables between groups, independent-samples *t* tests were used for means and chi-square tests were used for frequencies. To elucidate the effect of training, the differences on all dependent variables between the pre- and posttraining phases within group were analyzed by 1-way multivariate analysis of variance (MANOVA). Difference scores were calculated for each subject by subtracting the pretraining data from the posttraining data. Mean difference scores and the standard deviation (SD) of these changes scores were calculated for each variable. MANOVA was used to determine differences of mean difference scores of each dependent variable between groups. A significance level of .05 was set for all analyses.

RESULTS

Of the 25 subjects, 12 were randomly allocated to the control group, and the other 13 subjects were randomly allocated to the experimental group. Table 1 indicates the group means and SDs for age and stroke onset and the frequency counts for sex and hemiparetic side. There were no statistically significant differences between groups for age, stroke onset, sex, and hemiparetic side. Additionally, there were no significant differences between the experimental and control group in selected outcome measures before treatment. All subjects successfully completed the study protocol. In the experimental group, the attendance rate was 100% for the 4-week training program. All participants were able to perform the exercises as planned.

The gait performances under the single task and tray-carrying task are shown in table 2 and table 3, respectively. These results show that after the ball exercise training, significant improvement was found in all selected gait variables except for temporal symmetry index under both task conditions. On the contrary, improved gait performance was not shown in the control group. The between-group comparisons also revealed significant differences between the 2 groups for all selected gait variables except for temporal symmetry index under both task conditions.

DISCUSSION

This is the first published randomized controlled clinical trial study to examine the effectiveness of dual-task-based exercise training on walking ability in subjects with chronic stroke. Our results showed that a 4-week ball exercise program improved walking ability under single- and dual-task conditions in a group of limited community ambulatory (gait velocity between 58 and 80cm/s) and full community ambulatory subjects (minimum gait velocity, 80cm/s) with chronic stroke. After the intervention, the walking speed was increased from 85.62±19.85 to 115.35±18.14cm/s in subjects in the experimental group. It has been reported that a walking speed of 110 to 150cm/s is considered to be fast enough to function as a pedestrian in most environmental and social contexts.¹⁹ Furthermore, community ambulation is the ability to integrate walking with other tasks in a complex environment.¹⁴ Dual-task gait assessment may prove helpful in identifying those who may have difficulty generalizing gait performance during testing to a complex environment. In the present study, the gait performance under the dual-task condition was also improved after intervention. Therefore, this ball exercise program may help improve community ambulation function.

Table 2: Comparison of Single-Task Measures Within Groups and Between Groups

Measures	Values						Change Values		
	Control (n=12)		P*	Experimental (n=13)		P*	Control (n=12)	Experimental (n=13)	P†
	Pretest	Posttest		Pretest	Posttest		Post–Pre	Post–Pre	
Speed (cm/s)	92.42±31.19	79.58±15.75	.22	85.62±19.85	115.35±18.14	.001	–12.84±21.61	29.74±15.66	<.001
Cadence (step/min)	104.12±14.42	100.95±8.47	.52	95.72±8.51	110.69±10.66	.001	–3.16±10.07	14.98±9.42	<.001
Stride time (s)	1.21±0.10	1.15±0.14	.25	1.27±0.11	1.09±0.11	.001	–0.06±0.08	–0.16±0.10	.007
Stride length (cm)	102.07±18.11	105.05±22.53	.73	107.45±17.12	125.53±10.83	.004	2.97±12.84	18.08±9.97	.003
Temporal symmetry index	1.13±0.18	1.14±0.16	.95	1.12±0.09	1.08±0.12	.33	0.04±0.08	–0.04±0.09	.19

NOTE. Values are mean ± SD.

Abbreviation: Post–Pre, posttest–pretest.

*Significance level for within-group comparison.

†Significance level for between-group comparison.

Table 3: Comparison of Dual-Task Measures Within Groups and Between Groups

Measures	Values						Change Values		
	Control (n=12)			Experimental (n=13)			Control (n=12)	Experimental (n=13)	
	Pretest	Posttest	<i>P</i> *	Pretest	Posttest	<i>P</i> *	Post-Pre	Post-Pre	<i>P</i> †
Speed (cm/s)	72.78±20.20	85.70±30.40	.23	73.85±17.88	104.92±18.89	<.001	12.93±13.52	31.08±13.36	.003
Cadence (step/min)	94.92±7.75	102.83±14.90	.12	92.45±11.15	108.12±13.18	.003	7.91±9.08	15.66±10.64	.063
Stride time (s)	1.27±0.10	1.18±0.15	.12	1.31±0.16	1.13±0.16	.008	-0.09±0.09	-0.19±0.14	.045
Stride length (cm)	91.89±19.86	98.97±21.67	.41	95.37±16.19	116.00±10.63	.001	7.08±7.39	20.61±11.44	.002
Temporal symmetry index	1.17±0.19	1.16±0.16	.84	1.13±0.13	1.08±0.13	.33	-0.02±0.12	-0.05±0.08	.40

NOTE. Values are mean ± SD.

*Significance level for within-group comparison.

†Significance level for between-group comparison.

Previous studies have also shown exercise programs that resulted in improvements in the walking ability of stroke subjects who completed a rehabilitation program. Duncan et al²⁰ observed an average gain of 25cm/s after an 8-week, home-based exercise program that was designed to improve strength, balance, and endurance in subjects at an average of 66 days poststroke. Dean et al²¹ found that a 4-week training program on the performance of locomotor-related tasks led to an average gain of 12.6cm/s in subjects at a mean of 2.3 years poststroke. Furthermore, Ada et al⁹ introduced a concurrent cognitive task and designed a 4-week treadmill and overground walking program. They found that this 4-week treadmill and overground walking program was associated with an average gain of 18 cm/s in subjects with chronic stroke.⁹ A greater improvement in walking speed than those found in the previous studies was observed in the current study. An average gain of 29.74cm/s after a 4-week ball exercise program was found in a group of limited community ambulatory and full community ambulatory subjects poststroke. Thus, the ball exercise program may be an effective exercise program in improving walking ability.

In the present study, we used a gait assessment under dual-task conditions to evaluate walking ability. Because many daily activities involve concurrent motor components, the assessment of dual-task performance may provide a better index of functional daily ability compared with assessment under single motor task conditions. Based on our previous results,¹⁵ the tray-carrying task would be a suitable assessment for subjects with chronic stroke. This assessment is a useful and discriminative tool especially for full community ambulatory subjects. In comparison with our previous results, the mean walking speed under a tray-carrying task after ball exercise training was similar to that of healthy subjects (103.67cm/s).¹⁵ This finding also showed that the ball exercise program is an effective approach to improve walking ability.

A ball exercise regimen may seem useful in terms of promoting general fitness.²² The results of the present study showed significant improvement in walking ability after ball exercise. The reasons for the positive finding in this study remain unclear. However, the exercise we used in this study was a task-oriented program. Previous studies^{10,21} performed by using task-oriented intervention have shown significant improvement in locomotor function. In addition, 1 hypothesis²³ is that coordinated muscle activity may be stimulated when working at a high level activity. Furthermore, ball exercise may provide relevant feedback. Subjects were able to achieve a new skill. The ball provides the subject with information from their surroundings, helping the subject to integrate motor tasks in a complex environment. Moreover, ball activities could be an interesting program and could promote patient participation.

As noted, the attendance rate was 100% in the present study for the 4-week exercise program.

It is important to note that community ambulation should include multiple domains. In the present study, walking speed and a dual-task paradigm were measured with respect to community ambulation. Current measures are composed of items that researchers consider to reflect community ambulation, such as walking speed or endurance, functional mobility scales, or self-reported levels of activity.¹⁴ It is important to also consider measures that reflect the broader dimensions of community ambulation.

Study Limitations

There are several limitations in this study. First, the major limitation of this study was a lack of follow-up. We do not know whether the subjects in the experimental group were able to maintain these changes. However, ball exercise has the potential to encourage exercise habits on a long-term basis. Second, the sample size used in this trial was small, which implies that caution should be exercised when interpreting the results. Third, precaution must be taken in generalizing the results because our results are based on a selected group of participants suffering from chronic stroke with relatively high motor function. Finally, the study was limited to subjects who volunteered, and, therefore, they were a self-selected group of willing and highly motivated people.

CONCLUSIONS

The results of this study showed that a 4-week ball exercise program was followed by an improvement in the walking ability of a selected group of limited community ambulatory and full community ambulatory subjects with chronic stroke. The high participation rate in the ball exercise program should be considered in developing community-type exercise programs.

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Suppliers

- a. CIR Systems Inc, 60 Garlor Dr, Havertown, PA 19083.
- b. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.