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Original Research

Effects of Dual-Task Gait Treadmill Training on Gait Ability, Dual-Task Interference, and Fall Efficacy in People With Stroke: A Randomized Controlled Trial

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Abstract

Objective. This study aimed to investigate the effects of dual-task gait training using a treadmill on gait ability, dual-task interference, and fall efficacy in people with stroke.

Methods. Patients with chronic stroke (N = 34) were recruited and randomly allocated to the experimental or control group. Both groups underwent gait training on a treadmill and a cognitive task. In the experimental group, gait training was conducted in conjunction with the cognitive task, whereas in the control group, the training and the cognitive task were conducted separately. Each intervention was provided for 60 minutes, twice a week, for a period of 6 weeks for both groups. The primary outcomes were as follows: gait parameters (speed, stride, variability, and cadence) under single-task and dual-task conditions, correct response rate (CRR) under single-task and dual-task conditions, and dual-task cost (DTC) in gait parameters and CRR. The secondary outcome was the Fall Efficacy Scale.

Results. Dual-task gait training using a treadmill improved all gait parameters in the dual-task condition, speed, stride, and variability in the single-task condition, and CRR in both conditions. A difference between the groups was observed in speed, stride, and variability in the dual-task condition. Furthermore, dual-task gait training on a treadmill improved DTC in speed, variability, and cadence along with that in CRR, indicating true improvement of DTC, which led to significant improvement in DTC in speed and variability compared with single-task training.

Conclusions. Dual-task gait treadmill training was more effective in improving gait ability in dual-task training and dual-task interference than single-task training involving gait and cognitive task separately in people with chronic stroke.

Keywords: Dual-Task Condition, Gait, Rehabilitation, Stroke

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Introduction

Gait in daily life is composed not of walking alone but involves cognitive processing and attention to solve problems in various environments for safety. This means that gait is associated with cognition.[1,2] When 2 single tasks (cognition and motor) are simultaneously performed, dual-task interference (DTI), which indicates decreased performance of one or both tasks, occurs in an individual.[3] Changes in gait pattern by DTI show decreased gait speed and increased gait variability.[4] Changes in cognition lead to decreased verbal fluency and working memory.[5] Studies have reported that DTI can be provoked when attentional demands exceed the attentional capacity by simultaneously implementing 2 discrete tasks.[3,6,7] This is more prominent in individuals with stroke than in healthy individuals because of the capacity influenced by impaired motor and cognition.[4,8] In addition, high DTI is associated with high fall risk and decreased executive function in people with stroke.[9,10] A previous study showed that stroke patients with lower walking speed (< 0.8 m/s, limited community ambulator) had poor dual-task ability and higher DTI compared with those with high walking speed (> 0.8 m/s, full community ambulator),[4,11] indicating that those with lower speed (high DTI) need more specific dual-task training for levels of social participation. There are 2 principles that have been suggested to attenuate DTI in individuals with stroke. The first is task-specific training for dual-task ability, which involves increasing capacity processing for dual tasking.[12] Indeed, a number of studies have reported improved dual-task gait performance through task-specific training in individuals with stroke.[10,13–15] The second principle involves improving the automaticity of gait through repetitive practice, thereby reducing attentional demands for gait so that during dual tasking, resources available for secondary (cognitive) tasks relatively remain.[1,16–18] Although treadmill walking has been suggested as an intervention that induces automaticity through consistent and rhythmic movement in rehabilitation,[19,20] many studies have used over-ground walking rather than treadmill walking for dual-task ability.[2,7,10,21,22] In brain imaging studies for people with neurological diseases, the increased activation of the prefrontal cortex observed during dual-task gait due to poor automaticity and impairment of postural control was decreased, showing increased gait stability in the treadmill rather than in the over-ground gait.[1,17] Moreover, other recent studies also reported that compared with over-ground walking, treadmill walking improved performance of a cognitive task, which implied that as attention for walking decreased, a switch in attention to cognition had occurred.[16,18] Because people with stroke have impaired automaticity, impaired flexibility to switch attention into both domains, and excessive attention to the motor domain during dual-tasking relative to healthy people,[7,8,23] the use of a treadmill is important for dual-task training. The mechanical effect of the treadmill combined with dual tasking could reduce demands on cognitive control processes for gait and artificially limit changes of gait pattern incurred by DTI, such as decreased speed and stride, through the constantly backward-moving belt.[16,18,20] Taken together, we consider that performing dual tasks on the treadmill would improve dual-task gait ability through improvement of automaticity and task-specific practice along with improvement of cognitive tasks, and this would be a combination of task-specific training and automaticity. Therefore, this study aimed to determine the effects of dual-task training with a treadmill on gait ability under single- and dual-task conditions, DTI, and fall efficacy in individuals with stroke corresponding to a limited community ambulator (< 0.8 m/s). We hypothesized that dual-task gait treadmill training would improve gait ability, DTI, and fall efficacy more than single-task training involving motor and cognitive tasks separately.

Methods

Participants

This study was approved by the National Health Insurance Service Ilsan Hospital Institutional Review Board. All procedures were conducted in accordance with the Declaration of Helsinki. A total of 34 people with chronic stroke were recruited from the public hospital from February 20, 2020 to February 27, 2020. All testing and interventions were completed April 15, 2020. This study was registered at the Clinical Trial Registry of Korea (https://cris.nih.go.kr. No. KCT0004776; 28/02/2020). The 4 inclusion criteria were as follows: a score on the Korean version of the Mini-Mental State Examination of greater than 24; a walking speed of less than 0.8 m/s, indicating more exposure to DTI[4]; hemiplegia over 6 months after onset; and an ability to walk at least 10 m independently without using an assistance device. The 5 exclusion criteria were as follows: neurological diseases other than stroke; quadriplegia due to stroke; difficulty understanding instructions; orthopedic disorders causing pain during gait; and severe aphasia. All participants provided written informed consent before participating in the study.

Study Design

The study design was a single-blind, 2-arm, parallel, randomized, controlled trial. All participants were required to randomly select a numbered paper inside a sealed box and were allocated to the experimental group (dual-task gait training with treadmill) or the control group (single-task gait training with treadmill). All assessments were performed by a single researcher who was masked with regard to the allocation. All participants were asked to not reveal their respective group allocation until the initial assessment was completed. During the evaluation, only one participant was allowed in the evaluation room. All assessments were conducted at baseline and after 6 weeks of intervention.

Data Analysis

All statistical analyses were performed using SPSS 18.0 (IBM SPSS, Chicago, IL, USA). The values were indicated as the means and standard deviations. The differences in baseline participant characteristics between groups were analyzed using independent t tests and chi-square tests. The normality distribution of all outcome variables was checked using the Shapiro-Wilk test. A paired t test was used for within-group comparisons. For comparison between groups, analysis of covariance was conducted by setting covariates as preintervention variables. The significance level for all statistical processes was set at α equal to .05. The sample size was calculated using G∗power 3.1, with an effect size of 1.0, based on the outcome variable of a previous study.[14] A power of 0.80 and an α error of .05 were used and, thus, the sample size of 34 participants was calculated accordingly. To determine potential improvements in DTI, we conducted Pearson correlation analysis between baseline DTI and changes in DTI improvement.

Outcome Assessment

Gait Assessment

OptoGait (Microgate Srl, Bolzano, Italy) was used to analyze gait parameters at baseline and after 6 weeks of intervention. The equipment comprises a webcam and tens bars (1 m) including a transmitting bar and a receiving bar, and light-emitting diodes that are inserted at 1-cm intervals in each bar.[24] When a person walks between both side bars, gait parameters are detected, and information is collected through the installed light-emitting diode. Because these bars should be placed in parallel to analyze the gait pattern, the length bars (4 m) were placed in the middle of a 7-m walkway on both sides. The width bars were placed at the beginning and end of the walkway. The intrarater reliability was r equal to 0.93 to 0.99.[25] Extracted parameters were speed, stride, stance phase variability (ie, a percentage, calculated as [SD/mean] × 100), and cadence in the single-task and dual-task conditions. Each participant was instructed to walk 7 m to the turning point, where there was no sensor bar, and to return to the start line. While walking to the turning point, only the first middle 4-m section was analyzed, and the first and last stride were removed owing to acceleration and deceleration in this section. For the dual-task ability assessment, during the gait analysis described earlier, an additional cognitive task was applied simultaneously, which was a serial subtraction by 3 from 2-digit numbers randomly selected by the researcher.[10,26]

At the same time, the time to return to the start line and number of correct answers in the cognitive task were recorded using a stopwatch and recorder to evaluate the correct response rate (CRR), which has been extensively used to measure cognitive performance during dual tasking.[5,10] The formula for the CRR is as follows: CRR = (number of correct answers/time to complete task) × 100.

Next, to assess DTI for cognition, additional CRR under a single condition was calculated while sitting by applying the time obtained previously during the dual-task gait into the formula. Therefore, the sequence of assessment was as follows: gait tasks (single-task and dual-task conditions by randomization) and cognitive single task in a seated position.

In addition, during dual-task gait assessment, to prevent task prioritization, all patients received the following instruction: "walk, evenly distributing concentration between walking and the cognitive task." All trials were conducted twice, and the values were averaged accordingly.

Dual-Task Interference Assessment

To measure DTI, we used dual-task cost (DTC), which indicates the relative change from single-task ability to dual-task ability.[3,5,10] Here, a small relative difference indicates good performance. Many studies have evaluated motor DTC (eg, speed) alone without evaluating cognitive DTC even after intervention, and thus true improvement of DTI both in motor and cognition could not be observed.[13,21,27,28] To investigate overall DTI, motor DTC and cognitive DTC should both be concurrently assessed. True improvement in DTI is not the coexistence of amelioration and deterioration in motor or cognitive task performance (ie, task prioritization) but an improvement in the performance of both tasks.[3,5,10] Thus, for evaluating overall DTI, the DTC in all gait parameters and CRR were measured as follows: motor DTC = ([single-task gait parameter − dual-task gait parameter]/single-task gait parameter) × 100.

In the case of variability, where the lower value represents good performance, this formula was converted as follows: motor DTC = ([dual-task gait parameter − single-task gait parameter]/single-task gait parameter) × 100.

Cognitive DTC was calculated as follows: cognitive DTC = ([single-task CRR − dual-task CRR]/single-task CRR) × 100.

Therefore, in both domains (motor and cognition), lower values indicate decreased DTI (eg, improved DTI).

Fall Efficacy

The Fall Efficacy Scale, translated into Korean, was used to assess the fear of falling at baseline and after 6 weeks of intervention. It comprises 13 items associated with mobility, activities of daily life, and instrumental activities of daily life, with each item having a maximum of 10 points. A high score indicates a high fear of falling.[29]

Intervention

The intervention was provided for 30 minutes twice per week for 6 weeks for both groups. Each intervention comprised allocated treadmill training for 30 minutes and simple exercise for 30 minutes in the supine and sitting positions. Simple exercise included only passive stretching in the upper-extremity, hip, and knee areas. The experimental group performed gait training with a treadmill in conjunction with cognitive tasks comprising mental tracking, verbal fluency, and executive function, by therapists and experts associated with rehabilitation (Tab. 1),[6,23,30] followed by simple exercise.

The control group performed single gait training with a treadmill without concurrent cognitive tasks, but after treadmill training, cognitive tasks identical to those in the experimental group were applied along with simple exercise in only the supine and sitting positions, which was to avoid generating dual-task performance involving postural control while standing (ie, dual-task standing). Although the time and method of the applied cognitive tasks in both groups were the same, there was a difference in executive function tasks such as the Stroop task. In the experimental group, the participants performed the task on a treadmill while looking at the printed Stroop task paper attached to the wall 1 m ahead. On the other hand, participants in the control group performed the task only in a seated position in conjunction with passive stretching by therapists and experts while looking at the printed Stroop task attached to the chair. To adjust the level of tasks (motor and cognition), the treadmill belt speed applied was set at 80% of the dual-task gait speed obtained at the initial assessment during weeks 1 and 2 and gradually increased to 100% during weeks 3 and 4 and to 110% during weeks 5 and 6. Furthermore, for the postural control task, in different phases where the belt speed increased, participants were allowed to hold one safety bar on the sides of the treadmill with a comfortable hand during the first week but asked to free it during the second. Meanwhile, the therapist and expert associated with the rehabilitation were located as close as possible to the safety bar. Regarding cognition, the difficulty level of the cognitive tasks is shown in Table 1. These difficulty levels were divided into 2 phases: 1 to 3 weeks and 4 to 6 weeks. For the single-blind experiments, each intervention was applied in a different location. In addition, before the

Table 1. Applied Cognitive Tasks

Type	Instruction, 1–3 Wks	Level of Difficulty, 4–6 Wks
Working memory, 10 min		
Serial subtraction	Counting backward starting at a randomly selected number (100-300) (subtraction by 3, 4 or 6, etc)	Subtraction by 7 or 13
Speaking words backward	Reading backward word	Word with many letters
Verbal fluency, 10 min		Adjusted by ability of individuals
Speaking word	Saying word that fits presented category, (animal—lion, etc)	
Word chain	Coming up with words that begin with the letter that the previous word ended with	
Spontaneous speech task	Telling about proposed topic, (planning, recent news, etc)	
Executive function, 10 min		
Stroop task	Saying printed color of word, not the name of word itself	Stroop task with various words and colors

Table 2. Baseline Characteristics of Participants[a]

Baseline Characteristic	Intervention Group (n = 16)		Control Group (n = 15)		*P*
	Mean (SD)	No. of Participants	Mean (SD)	No. of Participants	
Age, y	56.94 (8.79)		56.13 (10.25)		.816
Sex					.208
Men		12		8	
Women		4		7	
Stroke type					.809
Infarction		6		5	
Hemorrhage		10		10	
Hemiparetic side					.605
Left		6		7	
Right		10		8	
Onset period, mo	56.31 (21.00)		53.07 (25.31)		.700
K-MMSE score	27.69 (1.96)		27.40 (3.09)		.758
Gait speed classification					.379
< 0.4 m/s		5		7	
0.4–0.8 m/s		11		8	
Use of cane					.594
Yes		7		8	
No		9		7	

[a]K-MMSE = Korean version of the Mini-Mental State Examination.

intervention, the therapist and expert shared and matched information on intervention methods twice a week.

Results

A total of 37 people were considered as potential participants. Only 34 of these met the inclusion criteria, were enrolled in the study, and were allocated randomly to either the experimental group (n = 17) or the control group (n = 17). Of these, 31 participants completed all interventions and assessments. During the study, 1 patient in the experimental group and 2 in the control group dropped out for personal reasons (Fig. 1). There were no significant differences in the characteristics or outcome variables between the groups (Tab. 2). During the study, no adverse events, such as a fall, were encountered.

Effects of Gait in Single-Task and Dual-Task Conditions

Changes in gait parameters after intervention are shown in Table 3. In the experimental group, significant differences between preintervention and postintervention were observed in speed ($P < .01$; $t_{15} = -3.65$), stride ($P < .01$; $t_{15} = -2.98$), and variability ($P < .01$; $t_{15} = 3.32$) in the single-task condition and in speed ($P < .001$; $t_{15} = -6.68$), stride ($P < .001$; $t_{15} = -5.46$), variability ($P < .01$; $t_{15} = 3.14$), and cadence ($P < .01$; $t_{15} = -3.00$) in the dual-task condition. In the control group, significant differences between preintervention and postintervention were observed in speed ($P < .01$; $t_{14} = -3.76$) and variability ($P < .01$; $t_{14} = 3.14$) in the single-task condition and speed ($P < .01$; $t_{14} = -3.82$) and cadence ($P < .01$; $t_{14} = -3.09$) in the dual-task condition. Significant differences between the groups were observed in speed ($P < .05$; $F_1 = 5.40$), stride ($P < .01$; $F_1 = 10.20$), and variability ($P < .05$; $F_1 = 4.26$) in the dual-task condition.

Effects of Motor and Cognitive Dual-Task Interference, and Correct Response Rate

Changes in DTC for motor and cognition after intervention are shown in Table 4. In the experimental group, there were significant differences between preintervention and postintervention in the DTC of speed ($P < .001$; $t_{15} = 4.37$), variability

Table 3. Comparison Between and Within Groups for Gait Parameters and Correct Response Rate in Single- and Dual-Task Conditions[a]

Parameter	Experimental Group			Control Group			P^c	Difference Between Groups (95% CI)
	Preintervention[b]	Postintervention[b]	Difference Within Groups (95% CI)	Preintervention[b]	Postintervention[b]	Difference Within Groups (95% CI)		
Single-task condition								
Speed, m/s	0.45 (0.14)	0.50 (0.14)	0.04[d] (0.02 to 0.07)	0.41 (0.19)	0.45 (0.19)	0.04[d] (0.02 to 0.06)	.841	0.00 (−0.03 to 0.04)
Stride, cm	70.69 (11.07)	75.20 (11.09)	4.51[d] (1.28 to 7.74)	70.51 (13.66)	71.63 (11.71)	1.12 (−2.42 to 4.65)	.110	3.43 (−0.83 to 7.69)
Variability, %	27.76 (8.26)	22.13 (9.53)	−5.63[d] (−9.34 to −1.91)	26.44 (10.96)	19.11 (8.73)	−7.33[d] (−12.33 to −2.32)	.397	2.22 (−3.08 to 7.52)
Cadence, steps/min	76.38 (18.76)	79.15 (15.59)	2.77 (−2.74 to 8.28)	67.29 (19.61)	72.19 (23.30)	4.90 (−0.46 to 10.26)	.761	−1.13 (−8.70 to 6.43)
CRR, %	30.79 (10.73)	41.02 (14.69)	10.23[e] (5.09 to 15.37)	38.23 (21.18)	43.08 (22.13)	4.85[f] (0.97 to 8.72)	.102	5.38 (−1.13 to 11.89)
Dual-task condition								
Speed, m/s	0.35 (0.13)	0.44 (0.13)	0.09[e] (0.06 to 0.12)	0.34 (0.18)	0.39 (0.18)	0.05[d] (0.02 to 0.07)	.028	0.04[f] (0.01 to 0.08)
Stride, cm	66.20 (9.28)	73.77 (9.98)	7.57[e] (4.61 to 10.53)	68.42 (12.75)	69.27 (11.54)	0.85 (−2.41 to 4.10)	.003	6.36[d] (2.28 to 10.44)
Variability, %	28.36 (12.05)	20.17 (8.94)	−8.19[d] (−13.75 to −2.63)	28.93 (13.60)	27.01 (10.38)	−1.92 (−9.91 to 6.07)	.048	−6.66[f] (−13.28 to −0.05)
Cadence, steps/min	64.34 (17.85)	72.91 (15.51)	8.57[d] (2.48 to 14.67)	56.96 (22.50)	66.53 (23.18)	9.57[d] (2.92 to 16.22)	.909	0.47 (−7.92 to 8.87)
CRR, %	17.58 (08.07)	27.70 (9.86)	10.12[e] (6.88 to 13.37)	21.82 (13.52)	26.26 (12.16)	4.44 (−0.49 to 9.37)	.090	4.68 (−0.76 to 10.11)

[a]CRR = correct response rate. [b]Values are reported as mean (SD). [c]Comparison between groups. [d]P less than .01. [e]P less than .001. [f]P less than .05.

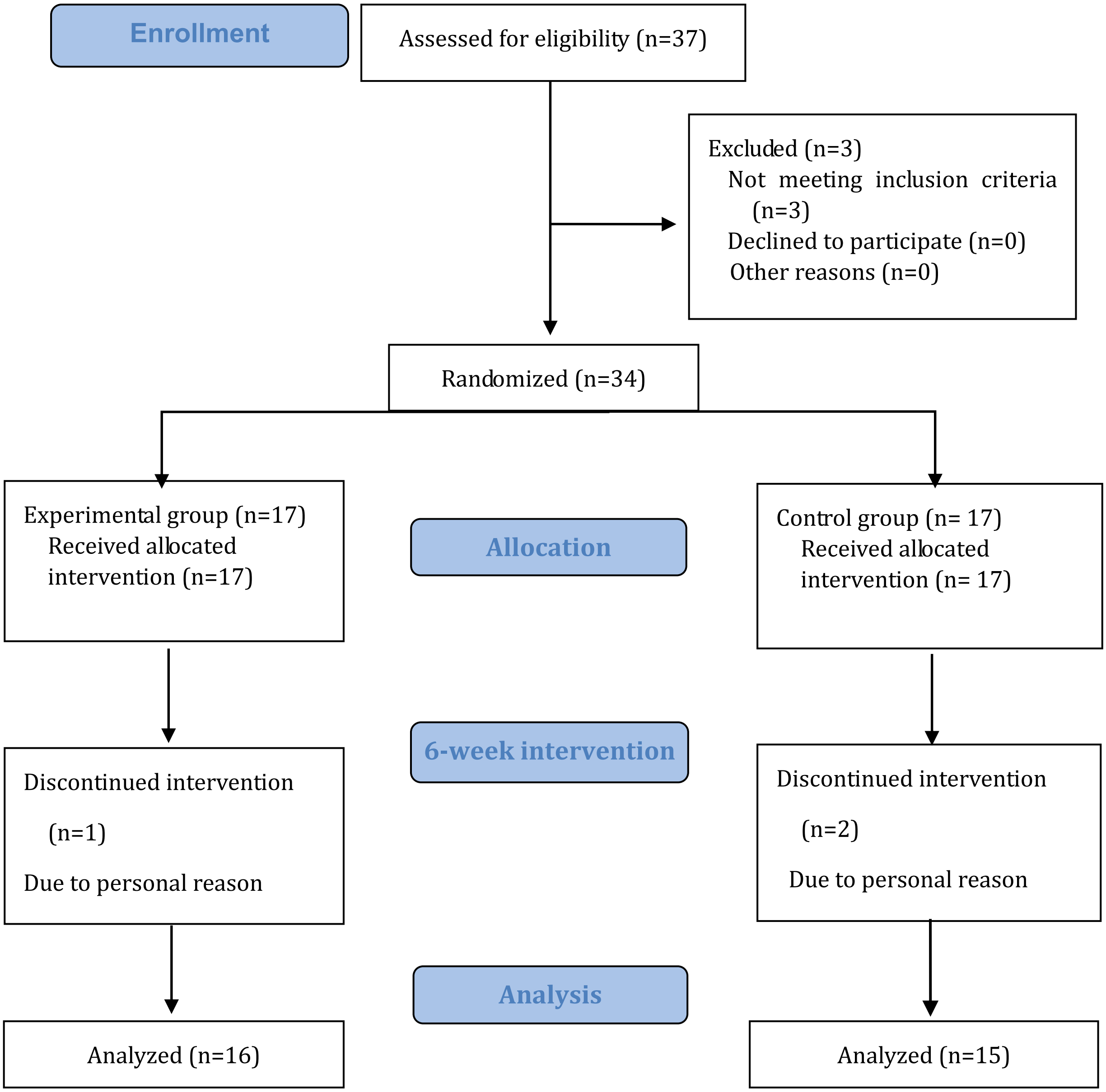

Figure 1. CONSORT flow diagram.

($P < .01$; $t_{15} = 3.37$), cadence ($P < .01$; $t_{15} = 3.03$), and CRR ($P < .05$; $t_{15} = 2.89$). In the control group, there was a significant difference after intervention in the DTC of speed ($P < .05$; $t_{14} = 2.49$). In the between-group comparison, significant differences were observed in the DTC of speed ($P < .05$; $F_1 = 5.05$) and variability ($P < .001$; $F_1 = 25.54$). Moreover, in the experimental group, to determine the potential effect of dual-task gait treadmill training in stroke patients with high DTI, Pearson correlation analysis was used and showed that each DTC at baseline was negatively correlated with change in DTC before and after intervention, that is, speed ($r = -0.785$; $P < .001$), stride ($r = -0.714$; $P < .01$), variability ($r = -0.862$; $P < .001$), cadence ($r = -0.634$; $P < .01$), and CRR ($r = -0.691$; $P < .01$) (Fig. 2). Regarding CRR, after each intervention significant differences were observed in CRR ($P < .001$; $t_{15} = -4.24$; and $P < .001$; $t_{15} = -6.65$) in both conditions in the experimental group. In the control group, there was a significant difference in CRR ($P < .05$; $t_{14} = -2.68$) in the single-task condition (Tab. 3).

Effects of Fall Efficacy

There was no significant difference in efficacy scale scores within groups preintervention and postintervention or between groups (Tab. 4).

Discussion

The purpose of this study was to investigate the effects of dual-task gait training using a treadmill on gait ability under single-task and dual-task conditions, DTI, and fall efficacy in individuals with stroke corresponding to a limited community ambulator (< 0.8 m/s). When measuring DTC, we evaluated DTC concurrently in motor and cognitive tasks to investigate overall DTI because previous studies have reported only the DTC of a motor task to evaluate overall DTI. An important

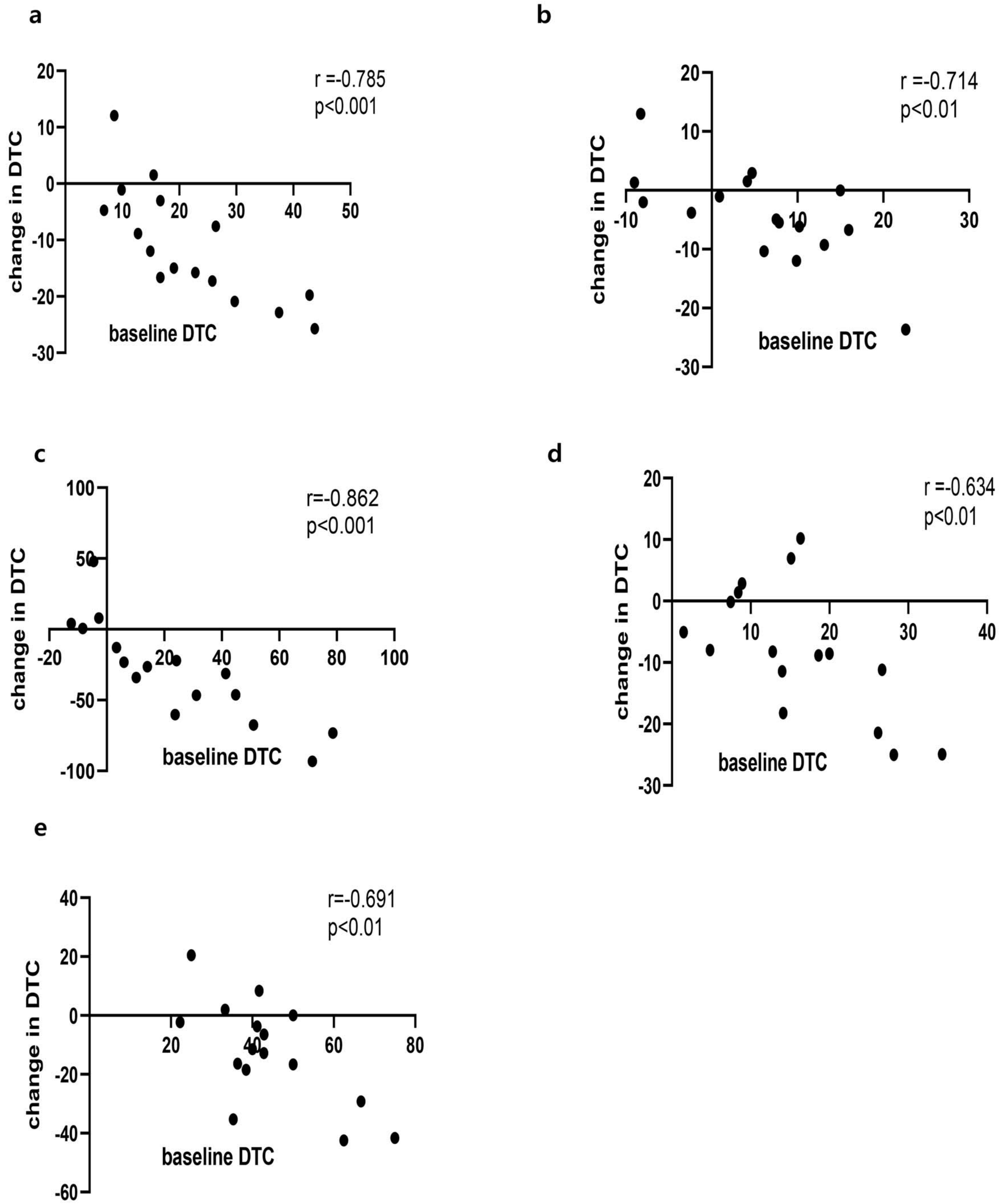

Figure 2. Relationship between dual-task cost (DTC) at baseline and change (pre-post) in DTC. (A) DTC of speed. (B) DTC of stride. (C) DTC of variability. (D) DTC of cadence. (E) DTC of correct response rate.

finding of the present study is that dual-task gait treadmill training improved dual-task gait performance and DTI in motor and cognitive tasks rather than single-task gait treadmill training involving motor and cognitive tasks separately.

Single-Task Gait Ability

In the single-task condition, speed, stride, and variability improved in the experimental group, whereas speed and variability improved in control participants after each intervention. There were no significant differences between groups, which may be because of the effect of the treadmill in common to both groups. This means that regardless of the application of dual tasks, treadmill training alone could improve automaticity and affect gait performance in the single-task condition.[31] Hence, speed in the single-task condition and variability in the single-task condition, indicating automaticity,[32] similarly improved in both groups. In contrast to the present study, the findings of Plummer et al showed that cognitive dual-task gait training did not improve single walking speed,[33] which may be due to differences in the environment (eg, over-ground). The findings by Dorfman et al showed that dual-task gait training using a treadmill improved single-gait performance in older patients.[19] In this respect, dual-task gait

Table 4. Comparison Between and Within Groups for Dual-Task Cost and Fall Efficacy[a]

Parameter	Experimental Group			Control Group			P^c	Difference Between Groups (95% CI)
	Preintervention[b]	Postintervention[b]	Difference Within Groups (95% CI)	Preintervention[b]	Postintervention[b]	Difference Within Groups (95% CI)		
DTC, % in motor task								
Speed, %	21.85 (11.67)	10.75 (7.31)	−11.10[d] (−16.52 to −5.68)	21.06 (11.26)	16.54 (12.99)	−4.52[e] (−8.41 to −0.63)	.033	−6.28[e] (−12.01 to −0.56)
Stride, %	5.65 (9.20)	1.48 (6.60)	−4.17 (−8.43 to 0.08)	2.29 (10.78)	3.01 (8.12)	0.72 (−6.20 to 7.65)	.384	−2.30 (−7.63 to 3.03)
Variability, %	23.26 (27.92)	−6.55 (18.11)	−29.81[f] (−48.66 to −10.95)	20.86 (60.94)	53.95 (43.51)	33.09 (−5.69 to 71.87)	< .001	−60.64[d] (−85.22 to −36.06)
Cadence, %	16.08 (9.16)	7.98 (8.61)	−8.10[f] (−13.80 to −2.40)	16.88 (15.68)	7.15 (15.84)	−9.74 (−20.43 to 0.96)	.818	1.04 (−8.11 to 10.19)
DTC, % in cognition task								
CRR, %	44.16 (14.51)	31.08 (12.98)	−12.87[e] (−22.32 to −3.43)	43.69 (15.73)	34.78 (17.06)	−7.05 (−17.12 to 3.01)	.253	−6.16 (−16.97 to 4.65)
Fall efficacy								
FES score	83.44 (27.45)	78.88 (17.86)	−4.56 (−21.65 to 12.52)	79.40 (26.81)	68.87 (30.47)	−10.53 (−35.72 to 14.66)	.253	10.50 (−7.93 to 28.94)

[a] CRR = correct response rate; DTC = dual-task cost; FES = Fall Efficacy Scale. [b] Values are reported as mean (SD). [c] Comparison between groups. [d] $P < .001$. [e] $P < .05$. $P < .01$.

treadmill training may affect single-task gait performance, but it is not superior to single-task gait treadmill for improving gait performance in the single-task condition.

Dual-Task Gait Ability

In the dual-task condition, in the experimental group, all gait parameters improved after intervention. In addition, significant differences were observed between groups in speed, stride, and variability. Similarly, the findings of a study by Cho et al reported that dual-task training with treadmill improved dual-task gait performance for individuals with stroke better than single-task gait training.[13] In addition, studies using treadmill training with people with Parkinson disease and older adults have shown improved dual-task gait performance.[19,20] In our study, gait performance involving variability indicating automaticity in the experimental group was significantly improved compared with that in the control group. This result suggests that because treadmill training and specific dual-task training were combined, the automaticity necessary for a dual-task environment would have occurred, which would have led to more improvement in gait performance in dual-task training than in single-task training. Furthermore, despite improvement in variability in the single-task condition, variability in the dual-task condition did not improve in the control group, which could indicate improved automaticity in the single-task condition would be insufficient to meet the necessary automaticity for the dual-task condition. These results were consistent with the findings of previous studies.[21,33] However, the study by Meester et al reported that dual-task training with a treadmill did not lead to significant improvement compared with control individuals.[23] This discrepancy could be attributed to the difference in gait ability of the participants and in interventions. The present study included participants with slow speed relative to those of a previous study (> 0.7 m/s) and did not allow holding the safety bar to adjust the difficulty of motor task. Also, because people with stroke with low speed had lower automaticity leading to exposure to more DTI relative to those with fast speed,[4,34] the dual-task training combined with treadmill responsible for improving the automaticity could improve dual-task performance in those with lower speed than single-task training.

The Dual-Task Cost of Motor and Cognition and Correct Response Rate Performance

In the experimental group, the DTC of gait performance and CRR improved after the intervention. Here, it is important to note that a concurrent decrease in DTC (motor and cognition) was observed, which indicates that the attentional capacity for dual-task processing had improved.[3] In the control group, improvement was observed in the DTC of speed alone, which is exposed to the possibility of a motor task prioritization strategy. In the comparison between the 2 groups, significant differences were found in the speed and variability DTC. This result is consistent with the findings of Pang et al, in whose study the most effective intervention method to reduce DTI was to practice dual-task training using task-specific concepts rather than single-task training.[10] Regarding the cognitive domain, no significant effects of intervention between groups were observed in CRR in the single-task and dual-task conditions as well as DTC of CRR. These results may be attributed to the fact that the applied treadmill speed was insufficient to decrease more cognitive DTI for people with stroke with excessive posture-first (motor over cognition).[8,18] Also, the findings of study by Penati et al showed that participants' cognitive DTC decreased at a fast speed because of automaticity generated by treadmill.[16] As observed earlier, our findings suggest that dual-task gait training on a treadmill is superior to single-task training for reducing DTI. Furthermore, we conducted a correlation analysis between the baseline DTC and degree of improvement in DTC to determine the potential improvement in DTC. In the experimental group, participants with a high DTC showed a high degree of improvement in DTC after intervention (Fig. 2). Consistent with our results, a previous study also showed the highest improvement in DTC after dual-task training in participants who had dementia and a high DTC at baseline.[35] These findings also suggest that specific dual-task training on a treadmill is needed to reduce DTI in patients with high DTI.

Fall Efficacy

There was no improvement in Fall Efficacy Scale scores after the intervention in either group. Several studies have shown no improvement in fall efficacy.[10,22,23] The findings of the study by Kim et al showed improved fall efficacy through dual-task training.[36] In their study, in addition to dual-task training with a kicking ball, the participants received general physical therapy for 1 hour, which comprised range of motion, strength, and balance exercise, all of which could affect fall efficacy.[37]

Study Limitations

This study has some limitations. First, it is difficult to generalize the results because of the small sample size as well as a decrease in the calculated sample size by dropout, and it is limited only to chronic stroke patients with lower gait speed. Second, because there was no follow-up test, it could not be determined whether there was a retention effect. Because one cognitive task (eg, subtraction) was applied in the evaluation, it could not be confirmed whether there was a transfer effect (eg, to other cognitive tasks). Finally, to determine the effectiveness of the dual-task training using a treadmill, a control group with ground walking is required. In the future, to better understand the efficiency of dual-task training with a treadmill, these aspects should be considered accordingly.

Conclusion

Dual-task training using a treadmill was more effective in improving dual-task gait ability and DTI than single-task training in patients with chronic stroke corresponding to a limited community ambulator. It can improve DTI, especially in patients with high motor and cognitive DTI.

Author Contributions

Concept/idea/research design: C.Y. Baek, W.N. Chang
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Ethics Approval

This study was approved by the National Health Insurance Service Ilsan Hospital Institutional Review Board. All procedures were conducted in accordance with the Declaration of Helsinki.

Clinical Trial Registration

This study was registered at the Clinical Trial Registry of Korea (https://cris.nih.go.kr. No. KCT0004776; 28/02/2020 to 15/04/2020).

Disclosures

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

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