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The effects of dual-task training on ambulatory abilities of stroke patients: Review of the latest trend

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Objective: Dual-task walking deficits impact functional daily life, which often requires walking while performing simultaneous tasks such as talking, thinking or carrying an object. This study is to find out the latest trend of dual-task training's influence on ambulatory abilities of a stroke patient.
Design: Systematic review of randomized controlled trials.
Methods: This literature review was conducted in Pubmed and Sciencedirect with the follwing key words:stroke, cerebro-vascular accident, hemiplegia, gait, rehabilitation, exercise. 7 studies were chosen in findings by search tool. 3 studies were case study, 3 studies were cross sectional observational study and 1 study was randomized controlled trial.
Results: It was found that stroke patients have difficulties in doing 2 motor tasks simultaneously and when they do 2 tasks, one is done in a naturally preferred activity areas. Moreover, when simply applying dual-tasks, the walking speed decreased. Meanwhile, when applying them through training, the speed increased. This showed the improvement of effective task-implementation abilities after dual-task training using task-integration models.
Conclusions: In the beginning of the 2000s, dual-tasks were implemented by simply combining walking and cognition or exercise task, and the results of this study suggest that subjects with stroke have difficulty performing dual task. However, the latest trend is to let patients do the dual-task training by combining it with virtual reality. Therefore, dual task training could be performed in a safe in the environment such as virtual reality or augment reality.

Key Words: Stroke, Task, Walking

Introduction

Stroke is a major problem that comes with aging. It leads to physical and sensory perception loss such as loss of motor skills and paresthesia. Moreover, it could trigger cognitive and social disabilities such as a speech disorder [1]. After 6 months it occurs, most physical functions are still deteriorated [2]. Accordingly, improvement potentials for physical functions should be increased through training based on the degree of patients' damaged function [3]. Loss and impairment of ambulatory abilities are one of the major devastating outcomes of post-stroke [4]. For those suffering from after effect of stroke, independent ambulatory abilities are an important goal in terms of rehabilitation program and for the combination with daily activities [5,6].

Since a series of tasks should be done in daily lives, people should be able to juggle exercise tasks and high cognitive functions simultaneously [7]. Dual-task training triggers development of strategic methods to implement several tasks at the same time [8,9]. Therefore, two models were proposed in order to explain changes related with dual-task training [9,10]. Task-automation model shows the improvement of dual-task implementation as each task's automation is increased. According to this model, dual-task implemen-

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tation is expected to be improved through single task and dual-task training. Meanwhile, according to task-integration model, effective combination of two tasks which were required for dual-task training play a decisive role in improvement of dual-task implementation. As a result, the improvement of dual-task implementation is not achieved through single-task training but through dual-task training [11].

Dual motor interference is considered as clinically important for reasons as follows. First, the simultaneous implementation of two exercise tasks could be a prescription itself for treatment. Second, the degree of interference according to dual-task differs among patients. Therefore, exercise implementation abilities of each individual could affect on treatment plans. Third, several exercise activities are done at the same time in most daily lives. Therefore, evaluation of dual-task implementation would be able to provide better standard in terms of evaluating functional daily abilities in comparison with single exercise task evaluation [7].

Accordingly, the aim of this study is to find out the latest trend of dual-task training's influence on stroke patients' ambulatory abilities.

Methods

With essential study subjects about dual-task for stroke patients, literatures -books, thesis, academic journals and internet information which were written by experts- were collected. The collection process was done through expert books, internet search and electronic searching program for thesis. Through literatures about dual-task, basic knowledge and latest authorized studies between 2001 and 2010, the latest trend was looked into.

To search information, for foreign literatures, medical thesis site (www.pubmed.com) and search site for scientific information (www.sciencedirect.com) which are provided by National Institute of Health were used. Moreover, through combined searching methods in which searching words such as stroke, cerebro-vascular accident, hemiplegia, gait, rehabilitation, exercise were used, periodicals and thesis were found.

The standard for searching was to select literatures in which dual-task was implemented to stroke patients over 30. Moreover, they should be studies that measured variables for walk. Animal test, contemplation study, methodological and theoretical discussions were exempted (Table 1).

Results

After searching latest study trend, 8 theses that befitted selection standard were found as shown in Table 2. Among

Table 1. List of inclusion and exclusion details

Area	Contents
Inclusion details	
Population	Any subjects over 30 years, studies with stroke patients
Study type	Intervention studies of any type, including case studies and non-randomized trials
Intervention	Dual task training (motor dual task and cognitive dual task)
Outcomes	Outcomes focus on gait parameters
Exclusion details	
Animal studies, reviews, methodological, theoretical or discussion papers	

Table 2. Included studies reported by design and subjects specifications

Study	Design	N	Subjects	Age (yr)
Plummer-D'Amato *et al*., 2010 [12]	Case study	8	Community dwelling adults with stroke	60.3
Kizony *et al*., 2010 [15]	CSOS	22	12 community dwelling adults with stroke/10 old adults	68.7
Dennis *et al*., 2009 [16]	CSOS	32	21 stroke patients/10 old adults	42-72
Plummer-D'Amato *et al.,* 2008 [13]	Case study	13	Community dwelling adults with stroke	60.5
Yang *et al.,* 2007 [7]	CSOS	45	15 full community ambulators post-stroke/15 least limited community ambulators/post-stroke, 15 age matched Healthy	41-77
Yang *et al*., 2007 [5]	RCT	25	13 community dwelling adults with stroke/12 community dwelling adults with stroke	45-80
Bowen *et al*., 2001 [14]	Case study	11	Adults with stroke	61-86

CSOS: cross sectional observational study, RCT: randomized controlled trial.

Table 3. Included studies reported by outcome measures, intervention and results

Study	Outcome measures	Intervention (E/C)	Results
Plummer-D'Amato *et al.*, 2010 [12]	DLS and swing duration of gait Reaction times	E: 3 different cognitive tasks in isolation and in combination with walking as well as a single walking task : 3 minutes C: none	Significant increase in DLS in dual-task walking (p=0.012) & paretic weight acceptance ($p<0.001$). Significant reduced the amount of time in paretic single-limb stance in the 3 dual-task conditions ($p<0.001$). No significant of temporal asymmetry under dual-task conditions. No significant of reaction times.
Kizony *et al.*, 2010 [15]	Gait speed, stride length, stride duration, cadence	E: Motored treadmill training in functional virtual reality C: same	General tendency to increase gait speed and stride length during dual-task conditions A significant effect of dual tasking was found only in one dual-task condition for gait speed (p=0.007), stride duration (p=0.028).
Dennis *et al.*, 2009 [16]	Gait speed Dual task score	E: cognitive dual task under self-selected gait speed & fast gait C: same	Stroke group decreased their walking speed while dual task. Mistakes in the visuo-spatial task during fast walking. During fast walking whilst concurrently performing a visuo-spatial imagery task, they appeared to prefered walking.
Plummer-D'Amato *et al.*, 2008 [13]	Gait temporal and spatial parameter Reaction time and accuracy score Spontaneous speech task	E: 3 different cognitive tasks while seated, and each cognitive task in combination with walking C: none	Significant dual task effects were observed for gait speed, stride time, average stride length, and cadence, but not for stride time variability ($p<0.05$). Speech produced more gait interference than memory and visuospatial tasks.
Yang *et al.*, 2007 [7]	Gait temporal and spatial parameter	E: Preferred walking (single task) Walking buttoning up (buttoning task) Walking while carrying a tray with glasses (tray-carrying task) C: same	No significant differences between full community ambulators and control subjects for all gait variables. Significant differences in dual task-related gait decrement between the full community ambulators and control subjects ($p<0.05$). Significant differences in dual-task related gait decrement between least limited community ambulators and control subjects ($p<0.05$).
Yang *et al.*, 2007 [5]	Gait temporal and spatial parameter Temporal symmetry index	E: ball exercise program 4 weeks: 3 times/week for 30 minutes C: not receive any rehabilitation training	Significant improvement in all selected gait measures post-intervention ($p<0.001$). Significant difference between groups for all selected gait variables except for temporal symmetry index under both task conditions ($p<0.01$).
Bowen *et al.*, 2001 [14]	Gait speed Double support time	E: single and dual task condition gait C: none	Significant decreased velocity in dual task condition (p=0.017). Significant increased double support time in dual task condition (p=0.01).

E: experimental group, C: control group, DLS: double limb support.

them, 1 studies [5] were randomized control trial. 3 studies [12-14] were case study and the rest 3 [7,15,16] were cross sectional observational study.

Ambulatory abilities can be classified into 2 sectors: spatial ambulatory ability and temporal ambulatory ability. For evaluation of ambulatory abilities, clinical evaluation methods such as ambulatory ability-evaluation equipment or community walk test are used. Walking speed, cadence, dual limb support degree mean temporal ambulatory abilities. Also, the result of evaluating step length and stride length mean spatial ambulatory abilities. In most studies, temporal and spatial ambulatory abilities were measured at the same time (Table 3).

Plummer-D'Amato *et al*. [12] let 8 stroke patients not only simply walk but also walk while doing other cognitive tasks. Then, changes in swing phase and dual limb support while walking were analyzed. As a result, paralyzed limb's phase of weight support was increased while doing 3 dual-tasks ($p < 0.05$). The swing phase of non-paralyzed limb was decreased while doing dual-tasks ($p < 0.001$). Moreover, 6 out of the total of 8 patients showed the increase of stand phase of non-paralyzed limb, having asymmetric walking aspects.

In studies of Kizony *et al*. [15], 12 stroke patients and 10 normal people were made to walk on tread mill according to their preferred walking speed. Then, researchers made them select virtual products on the screen which was set 1.5 m in front of them and showed a virtual grocery store. The walking speed of stroke patients was increased from 0.51±0.23 m/s to 0.74±0.42 m/s. Normal people's walking speed was increased from 0.87±0.13 m/s to 1.26±0.20 m/s. Stride length of paralyzed limb was increased from 0.62 m to 0.68 m.

Dennis *et al*. [16] argued that the interaction of cognitive task-implementation and walking speed differ according to walking speed. Therefore, using dual-task methods, the impact of the two cognitive tasks while walking with proper speed and fast speed on stroke patients were measured. At here, the two cognitive tasks were to subtract the number 3 consecutively and spatio-temporal tasks. In this process, cognitive task scores and walking speed were measured. When they consecutively subtracted the number 3 while walking both with preferred walking speed and fast speed, the walking speed was slowed. Moreover, when they walked in fast speed while doing spatio-temporal tasks, they made many mistakes and walked in their preferred speed.

Plummer-D'Amato *et al*. [13] let 13 stroke patients not only simply walk but also do 3 different cognitive tasks while seated and walking. In the process, walking speed, stride length and the change of cadence were measured. As a result, the walking speed was decreased while doing dual-task. Stride length and cadence were both decreased, Yang *et al*. [7] emphasized the importance of dual-exercise task in which two exercise tasks are implemented simultaneously rather than a dual task in which exercise task and cognitive task are done simultaneously. For example, in order to find out the influence of dual-task interference, abilities to implement exercise tasks were analyzed while 3 groups were walking. The 3 groups were classified as follows: those who can independently live after suffering stroke, those whose social lives are limited after stroke, and those who are normal. Exercise tasks included 1) simply walking in preferred speed (single task), 2) fastening a button while walking (dual task), and 3) holding a tray on which a cup is put while walking (dual task). At here, the walking variables between socially independent group and limited group after stroke showed no big difference. While doing dual-task rather than single task, walking speed of all group were decreased. However, the walking speed was even more significantly decreased for socially independent and limited groups after stroke than for normal group. While the independent group who walked outside did dual-task, the walking speed was decreased from 98.49±15.62 cm/s to 84.20±15.13 cm/s and 80.87±17.18 cm/s ($p < 0.05$). Cadence was decreased from 103.61±5.55 step/min to 99.58±3.70 step/min ($p < 0.05$) and 99.89±7.72 step/min ($p < 0.005$). Stride length was decreased from 114.81±13.23 cm to 101.88±16.49 cm and 96.55±13.05 cm ($p < 0.05$).

Yang *et al*. [5] let 13 residents who previously suffered stroke do dual-exercise task including 7 exercise activities using a ball. The training program included 1) walking while holding 1 or 2 balls on both hands, 2) walking 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), 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. As a result, the walking speed increased from 85.62±19.85 cm/s to 115.35±18.14 cm/s. Cadence was increased from 95.72±8.51 step/min to 110.69±10.66 step/min. Stride length was increased from 107.45±17.12 cm to 125.53±10.83 cm.

Bowen *et al*. [14] looked into the change of walking speed and both limb support of 11 stroke patients when doing a single task and dual-task. As a result, walking speed was decreased over 4 m/min. Both limb support increased from 18.9% to 20.9%.

Discussion

The first aim of rehabilitation is the increase of walking speed. However, simply increasing walking speed is not enough to set it as an indicator for a patient's returning to a society [5]. Accordingly, dual-task implementation while walking can be a significant indicator for returning to a society.

Dual-task training is to consecutively do more than 2 tasks simultaneously [17]. Since the relationship between cognition and exercise is related with the understanding of restoration of motor control after suffering neurological damage such as stroke, it have come to the fore of studies [7,13]. Cognitive motor interference (CMI) means a situation where single task or dual task are interfered while implementing them [13]. Conventionally, it is guessed that these interferences occur due to the need for concentration [18], according to recent studies, however, experts say that damaged executive control ability occur interference to CMI [19,20].

Through these studies, it was found that stroke patients have difficulties in doing 2 motor tasks simultaneously and when they do 2 tasks, one is done in a naturally preferred activity areas. Moreover, when simply applying dual-tasks, the walking speed decreased. Meanwhile, when applying them through training, the speed increased. This showed the improvement of effective task-implementation abilities after dual-task training using task-integration models.

Recent studies for dual-task training are mostly done in virtual-reality surroundings. This method can help researchers select a task that is normally seen in everyday lives and patients experience a similar environment of real one. Although current virtual reality program simply shows a programmed screen to a experiment participant, more vivid surroundings would be available in the near future.

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