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Effect of cognitive task on components of 7 meter timed up-and-go test in persons with stroke

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ABSTRACT: A problem dealing with dual task is commonly found in persons post-stroke but it is unclear whether age and educational levels influence this performance. The timed up-and-go test with cognitive task (TUG-dual) is recommended for assessing such problem but focusing only on total TUG time may mask the extent of cognitive tasks affecting each TUG component. This study investigates the effect of age and educational level on dual task performance during each component of TUG in patients with stroke. This cross-sectional study evaluated 25 patients with stroke and 25 healthy persons when performing 7 m TUG with and without counting backward by three. Total time to perform TUG, movement parameters, and rates of counting correct answers were measured. Four components of 7 m TUG (sit-to-stand, walk, turn, and turn-to-sit) were classified using portable accelerometers. The duration of TUG-dual increased in both groups but the amount of increase was larger in patients ($p < 0.001$). The rate of counting correct answer was affected by age ($p = 0.004$), but not educational levels ($p = 0.267$). In patients, the decreased rate of counting was found across all age ranges (35–54, 55–64, and 65–78 years), but in healthy persons, it was found only in the oldest age range. Cognitive tasks led to longer time during walk, turn, and turn to sit in patients. Changes in movement parameters including decreased peak angular velocity during turn and turn-to-sit, decreased stride length, stride velocity, and increased single leg stance time during walking suggested adaptation patterns in patients with stroke.

KEYWORDS: cerebrovascular accident, gait, turning, balance

INTRODUCTION

Everyday activities contain simultaneous performance of motor and cognitive tasks such as talking while walking. Patients who have had a stroke have problems dealing with cognitive-motor dual tasking. Reduction in motor performance during walking, including decreased walking speed[1], increased stride length and stride time[2], increased double limb support duration[3], and stop walking[4] is evident when patients are challenged by cognitive tasks during walking. The effect of cognitive task on gait performance is more pronounced during the more attention demanding task, as shown by decreased gait speed, decreased stride time before turning and increased time to turn[5] as well as decreased number of correct cognitive response[6]. Age[7] and education level[8] are the important factors for determining cognitive function. However, the effect of adding cognitive task on gait performance in persons with stroke who have different ages and level of educational attainment have not been revealed.

The timed up-and-go (TUG) test is the clinical test recommended for measuring basic mobility skills[9], especially walk to turn, in patients with stroke[10]. Cognitive task such as number subtraction has been introduced during the TUG to assess the cognitive-motor interference. The TUG test begins with rising from a chair, walking for 3 m at a comfortable pace, turning, walking back to the starting point and sitting down on the chair. This test is quantified by timing the duration from the start command until the buttocks touch the chair[9]. However, the total time for completing a TUG test appears to be an inadequate measurement of fall risk[10] and fails to detect change after three months post-stroke[11]. Focusing only on total time prevents

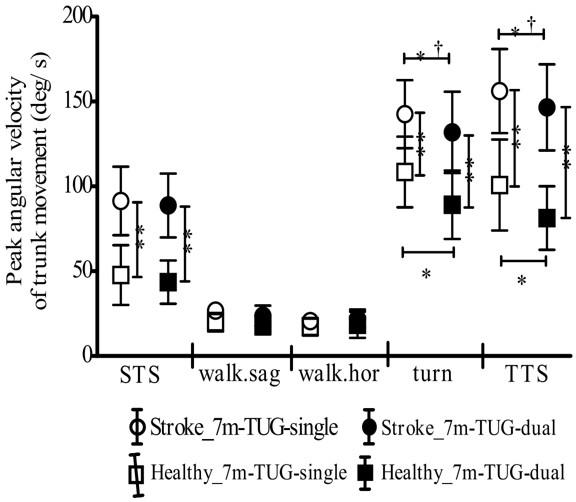

Fig. 5 Mean and SD of peak angular velocity of trunk movement under 7 m TUG-single and 7 m TUG-dual. STS =sit-to-stand component, walk.sag = walk component (sagittal plane), walk.hor = walk component (horizontal plane), turn = 180° turn component, and TTS =turn-to-sit component. * significant difference between TUG-single and TUG-dual; ** significant difference between groups; † significant task-group interaction.

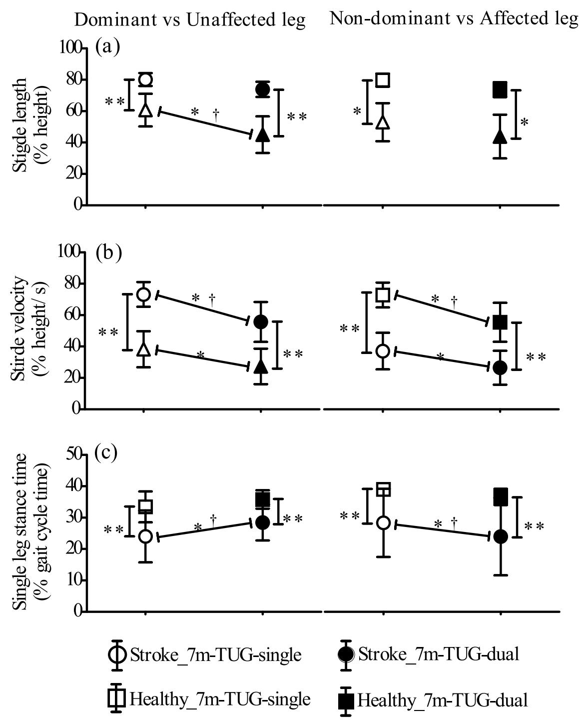

Fig. 6 Mean and SD of spatiotemporal parameters during walk component; (a) stride length, (b) stride velocity and (c) single leg stance duration under TUG-single and TUG-dual in patients with stroke and healthy persons. The left panel shows comparison between patients' unaffected leg and healthy's dominant leg and the right panel shows comparison between patients' affected leg and healthy's non-dominant leg. * Significant difference between TUG-single and TUG-dual; ** significant difference between patients and healthy persons; † significant task-group interaction.

than the healthy persons. Adding cognitive task led to significantly lower stride length of the unaffected limb (Fig. 6a), significant decreased stride velocity of both affected and unaffected limbs (Fig. 6b), decreased single leg stance duration of affected leg and increased single leg stance duration of unaffected leg (Fig. 6c). Healthy persons were also more affected by TUG-dual with fewer changes (i.e., decreased stride velocity of both legs) than patients (Fig. 6b).

During TUG-single, the average number of step during turn was 6.88 steps with an average step time of 0.78 s/step in patients and 5.52 steps with 0.59 s/step in healthy persons. Under TUG-dual, the average number of steps during turn was 7.20 steps with 0.88 s/step in patients and 5.65 steps with 0.69 s/step in healthy persons. Patients demonstrated significant higher number of steps ($F_{(1,48)} = 9.82$, $p < 0.01$) and longer step time ($F_{(1,48)} = 27.28$, $p < 0.01$) when compared to healthy persons during TUG-single and TUG-dual. Cognitive dual task affected both groups, as can be seen by significantly longer step time during turn ($F_{(1,48)} = 19.96$, $p < 0.01$), while number of steps remained unchanged ($F_{(1,48)} = 0.80$, $p = 0.37$).

DISCUSSION

This study aimed to clarify the effect of cognitive dual task on the components of 7 m timed up-and-go Test in patients with stroke. Results supported the hypothesis that there is a relationship between the degree of cognitive interference and components of TUG. The finding that patients with stroke and healthy persons increased time to complete 7 m TUG-dual as compared to 7 m TUG-single was in line with the previous literature, where elderly persons[24] and individuals with stroke[6] took longer to complete the cognitive TUG test as well as decrease rate of counting correct answer. A decline in performance of either cognitive or motor tasks, or both, under dual-task conditions has been described as cognitive-motor interference (CMI)[25]. The interference between central processing for cognitive and motor task occurs when tasks that share a common processing are concurrently performed. The amount of interference is related to the attention requirement of tasks, such that attention requirement that exceeds the limited central processing resources results in declined performance in either or both tasks, as compared to the performance of each task separately[26].

Patterns of CMI are classified into 9 categories; no change in task performance (no interference), decreased motor performance only (cognitive-related motor interference), stable motor performance with decreased cognitive performance (motor-related cognitive interference), declined performance of both motor and cognitive tasks relative to each other (mutual interference), increased performance of motor (motor facilitation) or cognitive performance (cognitive facilitation), increased performance of one task with declined performance of the other task (cognitive-priority trade-off or motor-priority trade-off), and increased performance of both tasks (mutual facilitation)[25]. In our study, two CMI patterns were found in healthy group. Healthy young persons demonstrated decreased 7 m TUG performance without a significant change in cognitive performance, suggesting cognitive-related motor interference. In contrast, healthy older adults showed decreased in both TUG and cognitive performances. This is classified as mutual interference pattern. A possible reason for CMI difference between young and older healthy persons is due to age-related working memory effectiveness. Counting backward task used in the present study is a type of working memory task that requires central processing to continue subtracting number.

Our finding of decreased performance of working memory task in healthy older persons corresponds with previous reported age-related percent of correct subtraction[27]. Age-related decreasing in performance of working memory task may be from reduced cognitive resources available for processing[28] and slowing of computational processes[29]. In addition, it has been shown that the ability to control balance reduced with age, thus attention requirement for maintaining balance is higher for older adults than younger subjects[26]. When performing multiple tasks simultaneously, the older adult may not have the capacity to perform both tasks, resulting in deterioration of both tasks[26]. A possible reason for no effect of education on cognitive task is that the counting backward task is a simple math task for all levels of educational attainments of our participants.

A decrease of both 7 m TUG and cognitive performance in patients with stroke, although with a larger deterioration than healthy, indicated mutual interference. Result on mutual interference during 7 m TUG-dual in patients with stroke corresponded with previous studies that measured performance when standing[30] or walking[31]. Cognitive impairment might not be a reason for such decreased cognitive performance in patients as they had normal cognitive levels and their MMSE scores were not different from those of healthy persons under cognitive-single. The possible reason for mutual interference in the patients may be due to limited postural reserve which could lead to high attention requirements for performing postural transition activities[32]. In the present study, patients with stroke had lower mobility and balance performance than healthy persons, thus low motor and balance capability could lead to higher attention requirement for controlling postural stability during 7 m TUG-dual. As a result, attention requirements may exceed capacity limits, leading to a larger decrease in both cognitive and motor performance in patients.

Our results also demonstrated that patients spent longer time during the walk, turn and TTS, but not the STS component. Some of patients stop counting during walk, turn, and TTS, but not STS and walk. In addition, only the increase in duration of walk component was more pronounced in patients than healthy persons. These results indicated that attention allocation for each TUG component was not equal; the largest attention demand occurred during walking, and the lowest was seen during STS. This finding could be partly explained by the requirement of large attention demand for persons with stroke to control lower extremity during walk. In the present study, all patients could walk without using gait aid; however, they still had some degree of lower extremity motor impairment (mean score of FM-LE = 28/54) and balance impairment (mean score of BBS = 40.35/56). These impairments may cause higher requirement for cortical control of walking[33]. Turning requires the coordination of eyes, head, limbs and trunk to provide anticipatory adjustments before changing the CoM position during sitting down[34]. However, short period of this activity may lead to less attention demand for carrying out dual-task compared to a long distance of walking component of 7 m TUG task. In contrast, sit to stand involves the control of trunk and limb movements to generate forward and upwards momentum of the CoM[35]; thus it may require less cortical control.

Changes in movement parameters suggested a compensatory strategy to maintain gait and balance when the attention was allocated for both cognitive task and TUG task. The decreased peak angular velocity of trunk movement during turn and TTS indicated the modulation of trunk rotation and step time during these TUG components when participants were distracted with cognitive tasks. Although both healthy older persons and patients showed decreased trunk turning velocity, the amount of decrease was larger in the patients. These characteristics were reported as turning difficulty in patients with chronic stroke[5,34]. On the other hand, this strategy may be accounted for by a cautious strategy or turning with safety[36]. We also observed the compensatory strategy during walk component of TUG-dual, but those strategies were not the same between healthy persons and patients. Healthy older persons adjusted speed of walking by decreasing stride velocity, leading to longer duration of walk component in TUG-dual. These findings were in line with a previous study reporting similar characteristics of gait modulation in elderly individuals who were challenged with dual tasks during walking[37]. In contrast, during TUG-dual, patients with stroke decreased stride velocity as well as demonstrated excessive asymmetrical gait pattern, as shown by decreased single leg stance time of affected leg and increased single leg stance time of unaffected leg. This compensation reflected inability to maintain stability of the moving CoM over the effected stance leg in patients with stroke when challenging with dual task[38], which could explain the need to decrease stride velocity and stride length in order to gain stability during walk component of TUG-dual.

Findings of this study were based on the use of the 7 m TUG where the walkway was 7 m instead of 3 m, thus the results from this study may differ when the original TUG test was used. The cognitive task examined in this study is the arithmetic task of counting backward by three. It is not known whether other types of cognitive task would affect TUG components in a similar way as the arithmetic task does. This question could be explored further in the future study. In addition, our study was carried out in high functioning persons with stroke who could walk without using a walking aid. The clinician should apply these findings specifically in patients with high mobility function.

Information from this study provides clinical implications for stroke rehabilitation. Although mutual interference during dual task walking found in both patients and healthy persons, the deterioration in walking performance was more pronounced in patients. Due to mutual interference pattern, training both motor and cognitive performances under dual tasking activity should be routinely practised in patients with stroke, even in those who can walk without using assistive devices. Performance assessment and training during dual task should focus on both walking and cognitive task. However, the training could be simplified for the beginners, for example, using treadmill during dual task training for improving automatic of walking (less attention requirement) and gaining community walking ability in patients with stroke.

In conclusion, the present study demonstrated that the effect of adding cognitive task of counting backward on TUG performance was varied among stroke patients with different age ranges, but not with different levels of educational attainment. The cognitive task affected components of TUG differently, depending on the cognitive requirement of the task in that component. Declining motor performance during TUG-dual, and the changes of acceleration-based movement parameters especially during walk, turn and TTS components found in patients with stroke, may help guide assessment and interventions directly towards components of the TUG that are more problematic.

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