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Association of dual-task walking with falls in community-dwelling individuals post-stroke: A prospective cohort study

Abstract

Background: Falling is common among individuals with stroke, and often occurs during dual-tasking. This study aimed to assess whether dual-task walking tests were useful in predicting falls compared with single-task walking tests in individuals with stroke.

Methods: Ninety-one individuals post-stroke (mean age: 62.7 ± 8.3 years; mean post-stroke duration: 105.5 ± 63.5 months) participated in this prospective cohort study. Each of the two mobility tasks, namely, forward walking (FW), and obstacle-crossing (OBS) were performed in isolation and also in conjunction with a verbal fluency task (VF). Participants were asked to perform both tasks equally well in dual-task conditions. The participants were then followed up monthly for a year to obtain the data on fall incidence, circumstances and related injuries, if any. Demographic information including age, gender, fall history, post-stroke duration, depressive symptoms, balance confidence, motor and cognitive deficit measurements were collected and included as covariates in multivariate binary logistic regression analysis to predict falls.

Results: Thirty-two percent of the participants reported at least 1 fall during the follow-up period, with a total of 71 fall episodes. Most falls occurred during walking. Fifty-six percent of the falls resulted in injuries. After adjusting for the effects of the covariates, increased dual-task effect (DTE) of walking time during OBS+VF was significantly associated with decreased risk of falls (multivariable adjusted OR= 0.951, 95%CI= 0.907-0.997, *p*= 0.037).

Conclusion: DTE on walking time during the OBS+VF dual-task condition was the most accurate in predicting falls amongst the single-task and dual-task walking parameters. This relatively simple dual-task walking assessment, together with simple demographics, has potential clinical utility in identifying people with stroke at high risk of future falls.

Key Words: dual-task; walking; cognition; falls; stroke.

INTRODUCTION

Falling is a great concern in individuals with strok. In addition to possible physical injuries [2, 3], falls may further lead to psychosocial consequences, such as depressed mood [4, 5] and reduced social activity [2, 4]. These physical and psychological consequences may result in reduced independence and a poor quality of life in people with stroke [2, 3, 6], steering researchers to search for useful tools to predict falls among people with stroke.

Many falls in older adults were found to occur during dual-task walking [7-12]. Dual-task interference (DTI), a decrement in either or both of the walking and secondary task performances compared with the single-task performances, has also been proposed to have a major contribution to the postural instability during balance and mobility tasks in healthy older adults [7, 11, 13]. Dual-task walking performance was thus suggested to be a better choice in predicting falls than the single-task walking performance in the elderly [8]. Given the more pronounced DTI in people with stroke compared with their able-bodied peers, [14-17] dual-task walking performance may be an even more important contributing factor to falls post-stroke.

Only a few studies [14, 18-20] explored the relationship between dual-task walking and falls post-stroke. In a study involving a sample of 32 individuals with subacute stroke, Baetens et al [18] observed significant differences in stride length percentage and nonparetic step length percentage between fallers and non-fallers during walking combined with a concurrent counting task, but not walking while naming animals. In another study of subacute stroke (91 participants), Andersson et al [20] found significant differences in performance in the Stop Walking While Walking Test between fallers and non-fallers, but time time taken to complete the Timed Up and Go (TUG) test in the single-task (TUG alone) and dual-task conditions (carrying a glass of water while completing the TUG) were similar between the two groups. In Hyndman et al [14], a reduced stride length was found to distinguish fallers from non-fallers in the people with chronic stroke when they performed a forward walking task while memorizing a seven-item shopping list. However, the sample size was small, involving only 36 individuals with chronic stroke and the falls were reported retrospectively. In another study by the same group of researchers, the usefulness of the “Stops walking while talking” test in predicting future falls among community-dwelling individuals with acute and chronic stroke was found to be questionable, with only a specificity of 70% and sensitivity of 53% [19]. Therefore, the fall predictive value of dual-task walking in individuals with chronic stroke remains uncertain.

The discrepancy in results among the above studies could be attributed to the types and complexities of both the walking and secondary tasks used, among other factors such as characteristics of the sample. Previous research has shown that the degree of DTI varied with different types and complexities of the walking and secondary component tasks [18]. It is thus likely that the usefulness of various dual-task walking tests in fall prediction would also differ. This study was undertaken to examine the predictive validity of the different single-task walking or dual-task walking tests. It was hypothesized that dual-task walking would be more useful in predicting falls than single-task walking tests in individuals post-stroke. The results may provide clinicians with important insights on the fall prevention strategies for people with stroke.

METHODS

This was a prospective cohort study. Ethical approval was granted by the Human Research Ethics Subcommittee of the University. All participants provided written informed consent prior to data collection.

Participants

Participants were recruited from local community self-help groups. We included individuals: 1) aged 50 years or above; 2) having a diagnosis of hemispheric stroke for 6 months or longer; 3) being medically stable; 4) living in the community; 5) having the ability to walk 10 meters with or without use of an assistive device; 6) and being able to follow given instructions. We excluded individuals: 1) having a neurological condition other than a stroke;

2) having pain during walking; and/or 3) having any other condition that may affect balance or walking.

Procedures

Apart from interviewing the participants for the demographic information, the Montreal Cognitive Assessment (MoCA)[14, 18, 20], color-word Stroop test[19], Activity-specific Balance Confidence (ABC) Scale[21-24], short form Geriatric Depression Scale (GDS-SF)[25], and Chedoke McMaster Stroke Assessment[26] was also assessed.

Dual-task and single-task paradigm

Participants performed each of the mobility tasks in a single-task context, then the dual-task walking, followed by each of the single cognitive tasks in sitting in a randomized sequence. The time given to perform the cognitive tasks was matched with the corresponding dual-task walking time. Participants were instructed to perform both tasks equally well in the dual-task conditions. A 10-minute rest period was provided between the single- and the dual-task procedures. Additional rest periods were also given upon request. Each condition was familiarized before the experiment.

The walking tests were completed along a 14m level ground walkway. In order to account for acceleration and deceleration of gait, only the time taken to walk the middle 10 m was measured with a stopwatch. The mobility tasks included: 1) forward walking (FW) [27-29]; and 3) forward walking while crossing a series of 7 obstacles (length 80cm, width 5cm, height 4cm) placed at every 1.5m along the middle 10-m section of a 14-m walkway (OBS) [30-32].

A verbal fluency task was used as the cognitive component task in our dual-task testing paradigm for its high relevance to daily living. Each mobility task was fixed to a particular category: FW with country naming, and OBS with food naming. Participants were asked to name as many words as possible during the designated time period. To avoid mental preparation or rehearsal, the specific word category was given when the participants approached start of the middle 10 m walking path during dual-task walking. The total number of answers and the correct responses were recorded. Good to excellent validity and reliability of these dual-task walking tests have been previously reported [33].

Prospective fall follow-up

Participants were followed up via telephone interviews about the fall incidence once a month for 12 months. A fall was defined as any unexpected resting of the body onto a lower surface without external displacing force like earthquake or medical conditions like a stroke, seizure or heart attack [27, 34]. They were finally categorized as either or non-fallers according to the prospective fall follow-ups.

Outcome Measures

Cognitive task performance was measured by “correct response rate (CRR)” calculated as: the total number of correct words generated/walking time [5, 30, 31, 35, 36]. The degree of DTI across different dual-task combinations was indicated by a percentage of dual-task effect (DTE, %) [37, 38]. To facilitate interpretation, the DTE was calculated to give a more positive DTE value for a worse dual-task performance compared with the single-task performance for both the walking time and CRR in all the dual-task conditions. The DTE on walking time was thus calculated as:

(*dual-task performance -single-task performance)/ single-task performance* × *100;*

while the DTE on CRR was calculated as:

(*single-task performance* − *dual-task performance*)/ *single-task performance* × 100.

Sample Size Estimation

A priori sample size estimation was performed using G*Power 3.1.9.2 (Universität Düsseldorf, Germany). Based on the number of fallers and non-fallers correctly identified by the dual-task assessments reported in two previous studies[19,20] , the odds ratios reported were 5.549 [20] and

2.629 [19]. With use of the more conservative odds ratio (2.629), a power of 0.8, an alpha of 0.05, a fall rate of 30%, and an attrition rate of 20%, a minimum of 85 participants was required.

Data Analysis

SPSS for Windows (version 23.0; IBM Corporation, Armonk, NY, USA) was used for statistical analyses. A pseudo intention-to-treat analysis was employed. If a subject was lost during the follow-up period, the fall status up to the point of losing contact were used for data analysis. First, the participants were classified into fallers and non-fallers according to the prospective fall follow-up results. Second, baseline between-group differences in participant characteristics were assessed with Mann-Whitney U test/ independent t-test and Chi-square test/ Fisher's exact test as appropriate. The demographic variables that demonstrated a significant difference between fallers and non-fallers would be entered as covariates in the multivariate binary logistic regression to predict fallers. Third, each of parameters derived from the single-task and dual-task walking tests was compared between fallers and non-fallers using Mann-Whitney U test/ independent t-test as appropriate. Finally, for each walking test variable that showed a significant between-group difference, a separate multivariate logistic regression analysis was conducted to determine whether the association with fallers remained significant after adjusting for the effects of the covariates (the demographic variables that showed a significant between-group difference, and also other risk factors of falls identified from previous studies including age [39, 40], gender [40, 41], depression [41-43], fall history [44, 45], visual deficit [46], cognitive deficit [43, 47], motor deficit [39, 44, 46], balance confidence [48, 49], and stroke duration [45]). Assumptions of multivariate logistic regression analysis including multicollinearity between independent variables were assessed [50]. A *p*-value <0.05 was considered as statistically significant.

RESULTS

Participant Characteristics

A total number of 107 participants were recruited and completed a telephone screening, but seven were lost to contact before the baseline assessment, one did not complete the mobility tests due to fatigue, and eight were excluded due to incomplete demographic data. Among the remaining 91 participants, one passed away at the ninth month of follow-up, and three were lost to contact at the second, eighth and eleventh-month telephone follow-up, respectively. Thirty-two percent of the participants were fallers (n= 29), of which 14 were single fallers and 15 were multiple fallers. The proportion of people having a fall history (p< 0.001) was higher in fallers than the non-fallers. Fallers also showed more lower limb impairments (p= 0.032) and lower balance self-efficacy (p= 0.010) (Table 1).

Table 2 shows the single-task and dual-task walking and cognitive task performances. Single-task walking time for the FW and OBS tasks were significantly longer among fallers than non-fallers ($p < 0.05$). Dual-task walking time of OBS was also longer among fallers than non-fallers. However, DTE on walking time of OBS+VF was greater among non-fallers than fallers. In other words, the non-fallers walked faster in both FW and OBS in the single-task condition and OBS in the dual-task condition, but demonstrated a greater DTI in dual-task walking of OBS+VF.

Fall incidence, circumstances and related injuries

Table 3 summarizes the frequency and circumstances of falls, and related injuries. Among all the fall incidents (n= 71), 56% resulted in injuries (n= 40), including one fracture (2.5% of all injurious falls) and 32 cases of bruising (80% of all injurious falls). Forty-five percent of the falls occurred outdoors (n= 32) whereas 38% occurred at home (n= 27). Sixty-five percent of the falls happened while forward walking (n= 46). The mostly self-perceived reason of falling was muscle weakness (25%; n= 18), followed by inattention (17%; n = 12).

Fall prediction models

As a significant between-group difference was shown in the single-task walking time of FW and OBS, dual-task walking time of OBS and DTE on walking time of OBS+VF (Table 2), separate multivariate logistic regression analysis was conducted to determine the association of each of these measures with falls, after adjusting for the effects of covariates.

Table 4 displays the results of the multivariable logistic regression analyses. After adjusting for the effects of the covariates, DTE on walking time of OBS+VF was the only significant fall predictor among all the measures (OR= 0.951, 95%CI= 0.907-0.997, p= 0.037). For every 1% increase in the DTE on walking time of OBS+VF, one was 4.9% less likely to sustain a fall (Table 5). Forty-seven percent (Nagelkerke R^2= 0.469) of the variance was explained by this model (χ^2= 32.116(12), p< 0.001). The overall percentage of correct classification from the model was 80.2. It correctly classified 88.7% of the non-fallers and 62.1% of the fallers.

DISCUSSION

Main findings

Amongst all the single- and dual-task mobility tests, DTE on walking time during the OBS+VF dual-task was the most accurate in predicting future falls among individuals with stroke.

Fall incidence, circumstances and related injuries

Consistent with previous reports, our results showed that most falls occurred during walking [2-4]. However, the fall rate we found (32%) was lower compared with previous studies in community-dwelling people with stroke (40-73%) [2-4, 51], but more similar to the population of community-dwelling older adults (32-34%) [52, 53] and a study done specifically on people with long-term stroke (mean post-stroke period of 10 ± 8 years, 23%) [5]. Our participants had long-standing stroke (mean stroke duration: 8.8 ± 5.3 years) and might have had many fall or nearly-fall experiences and developed their unique strategies in coping with the fall-prone situations, thereby resulting in a lower fall rate. Consistent with previous research, most fall occurred during walking [54, 55]. The percentage of falls that happened in an outdoor environment [51, 54] and the rate of serious injury and injury in total [55, 56] were also similar to findings from previous studies.

Fall prediction

In line with our hypothesis, DTE on the dual-task walking time was found to be more useful in future fall prediction than the single-task measures. This is consistent with findings from a recent systematic review reporting stronger associations between future falls and gait changes in dual-task walking compared with the single-task walking conditions among older adults [57].

Although a number of walking time-related parameters differentiated fallers from non-fallers, only the DTE on walking time for the OBS+VF condition showed significant fall prediction ability in multivariable logistic regression analysis. This might be explained by the greater attention load [58, 59] and a substantial challenge to the dynamic balance with obstacle crossing while concurrenlty engaging in the secondary verbal fluency task [60, 61]. FW is a walking task that well-practiced in daily living and thus more automated among our participants with chronic stroke [64, 65]. Successful execution of the OBS task requires more information processing and poses more challenge to the particiapnts. In fact, the time required to complete the OBS task in single-task condition was longer than that for the FW task (Table 2), confirming that the OBS task was more difficult than the FW task [35, 60, 62, 63].

The odds ratio obtained for the DTE on walking time for the OBS+VF dual-task condition (4.9%) is similar to that observed with the DTE on walking time for the walking while counting back (3%) dual-task in a study involving 258 high functioning community-dwelling older people [66]. Our results are also in line with previous work in young and older adults [9, 13, 66, 67] in that non-fallers generally tended to show a larger DTE on walking time (slower dual-task walking speed) than the fallers (Table 2). This suggests that the non-fallers tended to be more prudent. They would rather decrease their walking speed for optimizing their postural stability under the attention competing contexts of dual-task walking. As pointed out by

Kahneman [68] and other researchers [69, 70], the allocation of attention during dual-tasking is complex and highly flexible. Many factors including the given instruction on task prioritization, the individual's hazard estimation and the component task nature and complexities may affect the dual-tasking performance. Although the fallers also showed some decrease in the dual-task walking speed, the magnitude might not be sufficient enough to maintain their stability [13]. It is also possible that the single-task walking is quite demanding for the fallers already, as suggested by the trend of a longer single-task walking time taken by them (Table 2). This may have partly contributed to a smaller DTE in the fallers than the non-fallers. Nevertheless, this study showed that the dual-task OBS walking test has added value in identifying individuals at high risk of falls and should be incorporated in the overall gait assessment post-stroke.

In line with previous studies, fall history remained to be the strongest fall predictor [56, 71]. People having a history of fall were 8-fold more likely to fall than those without. However, it is not a modifiable factor. None of the single- or dual-task cognitive task parameters significantly differentiate fallers from the non-fallers. This might be attributed by the lower test-retest reliability of the cognitive task parameters as reported in previous dual-task walking studies in the populations of stroke [61, 72] and older adults [35, 62, 63].

Limitations

The results of the current study may only be generalized to community-dwelling stroke survivors with intact cognitive function and independent ambulation. The DTE used takes into account the level of single-task performance when quantifying the impact of the addition of the secondary task, and is the preferred indictor of severity of dual-task interference in many previous studies [59]. However, as the difference between the single- and dual-task performances is relative to the single-task performance, the corresponding single-task performance might inflate or deflate the DTE. Meanwhile, only VF, which tests the semantic verbal fluency, was used in the current study. Fall prediction of DTE in walking with other cognitive domains like the visuospatial cognition and discrimination and decision-making may worth further exploration. The relatively small proportion of fallers (*n*= 29) compared to non-fallers (*n*= 62) might have affected the precision of the effect estimation. It warrants future study with a larger sample size to verify the findings. Finally, although we had monthly telephone follow-ups for the fall incidence with our cognitively intact individuals with stroke, future studies might enhance the accuracy of data by distributing a fall diary to the participants for fall incidence recording.

CONCLUSION

Fall incidence and injury rate among community-dwelling individuals with stroke are high. Fall prediction is of paramount importance for formulating preventative strategies. Our results suggest that DTE of walking time with OBS+VF predicts falls better than the different standalone walking, or cognitive tasks, in individuals with chronic stroke. This short and simple dual-task walking assessment, together with other simple demographics, provides insights on the fall prevention strategies in the population with chronic stroke.

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