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COGNITIVE-MOTOR DUAL-TASK PERFORMANCE AND ITS ASSOCIATION WITH FUNCTIONAL MOBILITY AND FALL RISK AMONG PATIENTS WITH CHRONIC STROKE: A CROSS-SECTIONAL STUDY

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Abstract

Background: *Stroke is a major cause of long-term disability, and falls are a common and serious complication among survivors. Everyday walking usually requires simultaneous cognitive processing, so poor cognitive-motor dual-task performance may reduce functional mobility and increase the risk of falling. Evidence on this relationship in patients with chronic stroke is limited, and very few studies could be found from Pakistan.*

Methods: *This cross-sectional study included 69 patients with chronic stroke (at least 6 months after onset) at Hayatabad Medical Complex, Peshawar from July 2024 to December 2024, recruited through non-probability convenience sampling. Participants performed the Timed Up and Go test (TUG) alone and while counting backward in threes (TUG-cognitive). Motor and cognitive dual-task cost (DTC) were calculated. Functional mobility was assessed with the 10-meter walk test and fall risk with the Berg Balance Scale and self-reported falls. Data were analyzed using SPSS version 25.*

Results: *The mean age was 59.5 ± 8.1 years and 59.4% were male. The mean motor DTC was 21.8% and the mean cognitive DTC was 12.5%. Motor DTC was significantly negatively correlated with gait speed ($r = -0.79$, $p < 0.001$) and Berg Balance Scale score ($r = -0.74$, $p < 0.001$). TUG-cognitive time identified participants at high fall risk with an area under the curve of 0.93.*

Conclusion: *Greater cognitive-motor dual-task cost was associated with poorer functional mobility and higher fall risk among patients with chronic stroke, although the association of motor dual-task cost was not independent of single-task TUG time. Dual-task assessment was feasible, although it did not outperform single-task TUG time in identifying high fall risk.*

INTRODUCTION

Stroke is a leading cause of long-term disability, and many survivors live for years with persistent motor, balance and cognitive impairments. The burden is particularly high in South Asia, where stroke rates in middle-aged people have been reported to be five to ten times higher than in the United Kingdom and the United States, and cases are expected to rise with population ageing in developing countries such as Pakistan (1).

Falls are among the most frequent complications of stroke in the community (2). A meta-analysis of risk factors for falls in community stroke survivors identified impaired mobility (OR 4.36), reduced balance (OR 3.87), cognitive impairment (OR 1.75) and a history of falls (OR 1.67) as significant factors (3). Balance and mobility are also related to fall incidence in people with chronic stroke (4), and falls may lead to injury in older people with a history of stroke (5).

Walking is usually an automatic movement, but in daily life it is often carried out while attending to something else, such as talking, carrying objects or watching traffic. The dual-task paradigm examines how motor and cognitive performance interact when both tasks are done at the same time. When performance on one or both tasks gets worse, the effect is called cognitive-motor interference (6, 7). The size of this interference is commonly expressed as dual-task cost (DTC), which is the percentage change between single-task and dual-task performance (7, 8). After stroke, interference may be greater because of impaired motor control, executive function and attention (7).

Several clinical tests are used to assess dual-task performance, and the Timed Up and Go test with a cognitive task (TUG-cognitive) is widely used in stroke (6). Adding a secondary task has been reported to lengthen the time taken to complete the TUG by about 22 to 25% (6). In a study of 21 stroke survivors, counting backward increased TUG time by about 14% and 10-meter walk time by about 17% (9). In a prospective cohort of 91 community-dwelling people with chronic stroke, 32% reported at least one fall during follow-up, and the authors concluded that simple dual-task walking assessment has potential clinical utility in identifying people at high risk of future falls (10). Dual-task testing has also been used to predict falls in community-dwelling older adults (11).

However, important gaps remain. The reliability and validity of dual-task mobility assessments in chronic stroke are still being established (12), and the degree of interference depends on the type and difficulty of the cognitive task (6). Cross-sectional studies of dual-task interference in chronic stroke have often used small samples, for example 36 participants (8), and most evidence comes from high-income settings. In Pakistan in particular, evidence on how dual-task performance relates to functional mobility and fall risk in chronic stroke remains limited. This matters clinically, because a dual-task exercise program has been shown to improve dual-task mobility and reduce falls and fall-related injuries in people with chronic stroke who have intact cognition (13).

Therefore, the aim of this study was to determine the cognitive-motor dual-task performance of patients with chronic stroke and to examine its association with functional mobility and fall risk. We hypothesized that greater dual-task cost would be associated with poorer functional mobility and higher fall risk.

METHODOLOGY

Study Design

This was a cross-sectional study of cognitive-motor dual-task performance, functional mobility and fall risk among patients with chronic stroke. The study is reported according to the STROBE guideline for cross-sectional studies.

Study Settings

Hayatabad Medical Complex, Peshawar. Patients were recruited from the outpatient rehabilitation department, which receives referrals of stroke survivors from neurology, medicine and the community.

Study Duration

Study was conducted from July 2024 to December 2024 (6 months).

Sample Size

Sample size was calculated using G*Power with a bivariate correlation (two-tailed) test, an expected

medium effect size (r = 0.35), 80% power and alpha of 0.05. The minimum required sample size was 62 patients; allowing for 10% incomplete assessments, 69 patients were targeted. Because the exact number of chronic stroke patients attending the hospital during the study period was not known, a population-based formula was not used. The sample size for this study turned out to be 69.

Sampling Technique
Non-probability convenience sampling

Inclusion Criteria:
- Male and female patients aged 18 years and above
- Diagnosis of first or recurrent stroke (ischemic or hemorrhagic) confirmed by CT, MRI or medical records
- At least 6 months after stroke onset (chronic stroke)
- Able to walk independently for at least 10 meters, with or without a walking aid
- Montreal Cognitive Assessment (MoCA) score of at least 18

Exclusion Criteria
- Other neurological conditions such as Parkinson disease or multiple sclerosis
- Severe aphasia, or visual or hearing impairment that prevents performance of the tasks
- Orthopedic or musculoskeletal conditions affecting gait (for example fracture or amputation)
- Unstable cardiovascular disease
- Cognitive impairment below the MoCA cut-off

Data Collection Procedure
Data were collected using non-probability convenience sampling. All participants were screened for the inclusion and exclusion criteria. Eligible participants were given detailed information about the study and written informed consent was taken before participation. Demographic and clinical data (age, gender, time since stroke, type of stroke, affected side, use of a walking aid and falls in the previous 6 months) were recorded. All assessments were performed in one session by two trained physiotherapists, with rest between trials to avoid fatigue.

Dual-task performance:
Participants first performed the Timed Up and Go test (TUG) as a single task. They stood up from a standard chair, walked 3 meters at a comfortable speed, turned, walked back and sat down, and the time was recorded in seconds. The cognitive single task was counting backward in threes from a random number between 90 and 100 for 30 seconds while seated, and the number of correct responses was recorded. In the dual-task condition (TUG-cognitive) the participant performed the TUG while counting backward in threes. Participants were instructed to walk as quickly and safely as possible while counting, without giving priority to either task, and the order of the single-task and dual-task conditions was randomized. Motor and cognitive DTC were calculated as follows:
Motor DTC (%) = (TUG dual-task time − TUG single-task time) ÷ TUG single-task time × 100
Cognitive DTC (%) = (correct responses single task − correct responses dual task) ÷ correct responses single task × 100
For both measures a higher value indicates greater dual-task interference.

Functional mobility:
Functional mobility was assessed with the single-task TUG time and the 10-meter walk test.

Fall risk:
Fall risk was assessed with the Berg Balance Scale, in which a score below 45 indicates high fall risk and by self-reported falls in the previous 6 months. A fall was defined as an unexpected event in which the participant came to rest on the ground, floor or a lower level. Participants were classified as high or low fall risk and as fallers or non-fallers.

Data Analysis Procedure:
Data was processed using Statistical Package for the Social Sciences (SPSS) version 25. Descriptive analysis was used for socio-demographic and clinical variables. Mean and standard deviation were used for numerical variables such as age, time

since stroke, TUG time and DTC, and frequencies and percentages for categorical variables such as gender, stroke type and fall status. Normality was checked with the Shapiro-Wilk test. Single-task and dual-task performance were compared using Wilcoxon signed-rank test. The association of DTC with functional mobility and fall risk was tested using Spearman correlation, and categorical variables were compared using the chi-square test. Multiple linear and binary logistic regression was used to examine the independent association of DTC with functional mobility and high fall risk, adjusting for age, time since stroke, motor impairment, cognitive score and single-task TUG time. Receiver operating characteristic (ROC) analysis was used to find the ability of TUG-cognitive time to identify participants at high fall risk, and the cut-off was selected using the Youden index. A p-value of less than 0.05 was considered statistically significant. Because time since stroke, TUG time (single and dual-task) and cognitive DTC deviated from normality (Shapiro-Wilk $p < 0.05$), non-parametric tests were used throughout. Differences in continuous variables between the high and low fall risk groups were tested with the Mann-Whitney U test, and the proportion of fallers between the two groups with the chi-square test. The strength of Spearman correlation was interpreted as weak (below 0.40), moderate (0.40 to 0.69) or strong (0.70 and above). Gait speed from the 10-meter walk test was the functional mobility outcome for linear regression and high fall risk (Berg Balance Scale below 45) was the outcome for binary logistic regression. The linear model included motor DTC, cognitive DTC, age, time since stroke, single-task TUG time, lower-limb motor impairment (Fugl-Meyer lower extremity score) and cognitive score (MoCA). Because only 16 participants were in the low-risk group, the logistic model was limited to five covariates (motor DTC, cognitive DTC, age, time since stroke and single-task TUG time) and is reported as adjusted odds ratios with 95% confidence intervals. Multicollinearity was checked with the variance inflation factor (acceptable below 5). The 95% confidence interval of the area under the ROC curve was calculated by the Hanley-McNeil method.

Ethical Consideration:

This study was approved by Institutional Review Board / Ethics Committee, Hayatabad Medical Complex, Peshawar, approval number [XX] and by Hayatabad Medical Complex, Peshawar for data collection. Informed consent was taken from all included participants.

RESULTS

Demographic and Clinical Characteristics of Participants

After completing the assessment and meeting our inclusion criteria, 69 patients with chronic stroke were added to the study. The mean age of the participants was 59.5 years, with a standard deviation of ± 8.1. The participants ranged in age from 40 to 76 years, with 41 males and 28 females, resulting in 59.4% and 40.6% of the sample, respectively. The mean time since stroke was 40.8 ± 23.5 months. 47 (68.1%) participants had ischemic stroke and 25 (36.2%) reported at least one fall in the previous 6 months.

The clinical and demographic information of the participants is displayed in Table.1.

TABLE .1

Participants' Clinical and Demographic Details (n = 69):

Variable	Categories	Frequency(n)	Percentage (%)	Mean ± SD
Age(years)				59.5 ± 8.1
Gender	Male	41	59.4%	
	Female	28	40.6%	
Time since stroke				40.8 ± 23.5 months

Type of stroke	Ischemic	47	68.1%	
	Hemorrhagic	22	31.9%	
Affected side	Right	38	55.1%	
	Left	31	44.9%	
Use of walking aid	Yes	23	33.3%	
	No	46	66.7%	
Fall in previous 6 months	Yes	25	36.2%	
	No	44	63.8%	

Single-task and dual-task performance

Compared with the single-task condition, TUG time increased from 15.9 ± 5.9 seconds to 20.0 ± 9.1 seconds under the dual-task condition ($p < 0.001$), corresponding to a mean motor DTC of 21.8 ± 12.4%. The number of correct responses decreased from 11.0 ± 2.4 to 9.7 ± 2.6 ($p < 0.001$), corresponding to a mean cognitive DTC of 12.5 ± 9.0%. Details are shown in Table.2.

Table .2
Single-task and dual-task performance and dual-task cost (n = 69)

Measure	Single task (Mean ± SD)	Dual task (Mean ± SD)	DTC (%)	p-value
TUG time (seconds)	15.9 ± 5.9	20.0 ± 9.1	21.8 ± 12.4	<0.001
Correct responses (n)	11.0 ± 2.4	9.7 ± 2.6	12.5 ± 9.0	<0.001

Wilcoxon signed-rank test; values are mean ± SD. DTC is the mean of individual cost percentages.

Association of dual-task performance with functional mobility and fall risk

Motor DTC was negatively correlated with gait speed ($r = -0.79$, $p < 0.001$) and with Berg Balance Scale score ($r = -0.74$, $p < 0.001$), and cognitive DTC was also significantly correlated with gait speed ($r = -0.57$, $p < 0.001$). The correlations are presented in Table.3.

Table .3
Correlation of dual-task measures with functional mobility and fall risk (n = 69):

Variable	Gait speed (10MWT) r (p-value)	Berg Balance Scale r (p-value)
Motor DTC	−0.79 (<0.001)	−0.74 (<0.001)
Cognitive DTC	−0.57 (<0.001)	−0.45 (<0.001)
TUG-cognitive time	−0.88 (<0.001)	−0.84 (<0.001)
TUG single-task time	−0.86 (<0.001)	−0.83 (<0.001)

Spearman correlation coefficients (p-values); gait speed from the 10-meter walk test.

Comparison between participants with high and low fall risk

Participants classified as high fall risk (53, 76.8%) had higher motor DTC (25.3 ± 11.3% vs 10.0 ± 7.9%, $p < 0.001$) and longer TUG-cognitive times (22.6 ± 8.6 s vs 11.1 ± 2.9 s, $p < 0.001$) than those at low fall risk (Table.4).

Table .4
Dual-task measures according to fall risk status:

Variable	High fall risk (n = 53)	Low fall risk (n = 16)	p-value
Motor DTC (%), Mean ± SD	25.3 ± 11.3	10.0 ± 7.9	<0.001
Cognitive DTC (%), Mean ± SD	13.8 ± 8.8	8.1 ± 8.3	0.019
TUG-cognitive time (s), Mean ± SD	22.6 ± 8.6	11.1 ± 2.9	<0.001
Faller in previous 6 months, n (%)	23 (43.4%)	2 (12.5%)	0.024

Independent association and discriminative ability

In the multiple linear regression model adjusted for age, time since stroke, single-task TUG time, lower-limb motor impairment (FMA-LE) and cognitive score (MoCA), motor DTC did not remain independently associated with gait speed (β = −0.0019, 95% CI −0.0056 to 0.0017, p = 0.289) (Table.5). ROC analysis showed that TUG-cognitive time identified participants at high fall risk with an area under the curve of 0.93 (95% CI 0.87–0.99). A cut-off of 13.7 seconds gave a sensitivity of 90.6% and a specificity of 87.5% (Figure 1).

In this model, cognitive DTC (β = −0.0034, 95% CI −0.0068 to −0.0001, p = 0.046), single-task TUG time (β = −0.0127, 95% CI −0.0209 to −0.0044, p = 0.003) and lower-limb motor impairment (FMA-LE) (β = 0.0090, 95% CI 0.0003 to 0.0178, p = 0.043) were independently associated with gait speed, whereas age, time since stroke and MoCA score were not (Table.5). The model explained 81.7% of the variance in gait speed (adjusted R^2 = 0.797). In the binary logistic regression model for high fall risk (Berg Balance Scale below 45), adjusted for motor DTC, cognitive DTC, age and time since stroke, only single-task TUG time remained independently associated with high fall risk (OR = 1.86 per second, 95% CI 1.16–2.97, p = 0.010), whereas motor DTC (OR = 1.04, 95% CI 0.92–1.19, p = 0.530) and cognitive DTC (OR = 0.99, 95% CI 0.87–1.12, p = 0.833) did not (Table.6). Variance inflation factors were below 5 for all predictors.

Table .5
Regression analysis of factors associated with gait speed (multiple linear regression, n = 69; R^2 = 0.82, adjusted R^2 = 0.80):

Variable	β (unstandardized)	95% CI	p-value
Motor DTC (%)	−0.0019	−0.0056 to 0.0017	0.289
Cognitive DTC (%)	−0.0034	−0.0068 to −0.0001	0.046
Age (years)	−0.0010	−0.0045 to 0.0025	0.557
Time since stroke (months)	0.0004	−0.0007 to 0.0015	0.460
TUG single-task time (s)	−0.0127	−0.0209 to −0.0044	0.003
Lower-limb motor impairment (FMA-LE)	0.0090	0.0003 to 0.0178	0.043
Cognitive score (MoCA)	0.0132	−0.0022 to 0.0286	0.091

Table .6
Regression analysis of factors associated with high fall risk (binary logistic regression; high risk n = 53, low risk n = 16):

Variable	OR (adjusted)	95% CI	p-value
Motor DTC (%)	1.04	0.92–1.19	0.530
Cognitive DTC (%)	0.99	0.87–1.12	0.833
Age (years)	1.04	0.92–1.18	0.510
Time since stroke (months)	1.00	0.96–1.05	0.969
TUG single-task time (s)	1.86	1.16–2.97	0.010

FIGURE .1

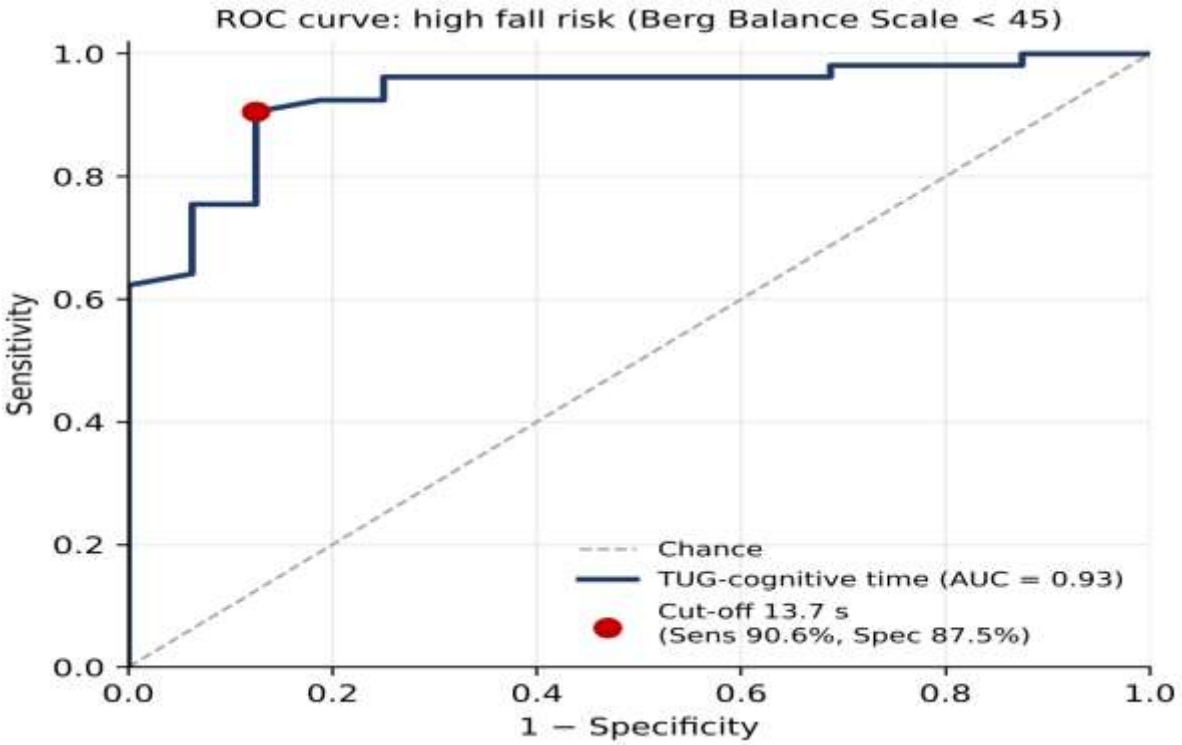

Figure 1. ROC curve of TUG-cognitive time for identifying participants at high fall risk (Berg Balance Scale below 45). AUC = 0.93 (95% CI 0.87–0.99); optimal cut-off 13.7 s (Youden index), sensitivity 90.6%, specificity 87.5%. For comparison, the AUC of single-

DISCUSSION

A cross-sectional study was conducted on 69 patients with chronic stroke to examine cognitive-motor dual-task performance and its association with functional mobility and fall risk. The main finding was that greater motor and cognitive dual-task costs were associated with poorer functional mobility and higher fall risk, although the association of motor dual-task cost with these outcomes was attenuated after adjustment for age, time since stroke and single-task mobility.

Dual-task performance in chronic stroke

The mean motor DTC in our participants was 21.8% (TUG) and the mean gait speed cost was 17.4%. This is partly consistent with earlier work in stroke survivors, in which dual tasking increased TUG time by about 14% and 10-meter walk time by about 17% (9), and in which a secondary task

lengthened TUG completion time by about 22 to 25% (6). Differences in the size of interference may be explained by the cognitive task used, because the degree of dual-task interference depends on the type and complexity of the task (6), and by differences in sample characteristics. Increasing cognitive load and prioritizing the cognitive task have also been shown to prolong TUG time in people with stroke (7), so instructions should be standardized when results are compared across studies.

Association with Functional Mobility

The association between DTC and functional mobility supports the view that attentional demands contribute to everyday walking after stroke. When walking is less automatic, more cognitive resources are needed to maintain gait and fewer remain for the second task. In our sample, motor and cognitive DTC were both strongly and negatively correlated with gait speed, but after adjustment only cognitive DTC and single-task TUG time remained independently associated with gait speed (Table.5). Motor DTC and single-task TUG time were highly collinear (variance inflation factors 3.7 and 4.3), so much of the apparent effect of motor DTC probably reflects underlying single-task walking ability. Baek et al. (8) studied the degree of dual-task interference in relation to gait, cognition, balance and fall efficacy in 36 people with chronic stroke; our larger sample (n = 69) allowed adjustment for several covariates at once. Reliability and validity evidence supports the use of dual-task mobility assessments in chronic stroke (12).

Association with Fall Risk

With regard to fall risk, TUG-cognitive time (AUC 0.93) and motor DTC (AUC 0.90) discriminated between participants at high and low risk. This agrees with a prospective cohort of 91 people with chronic stroke, in which dual-task walking assessment was suggested as a way to identify people at high risk of future falls (10). Impaired mobility, reduced balance and cognitive impairment are established risk factors for falls after stroke (3), which fits with the idea that combined motor and cognitive demands expose these deficits. Because our design was cross-sectional, our results describe association with current fall risk status and past falls only, and cannot show that dual-task performance predicts future falls.

However, single-task TUG time discriminated high from low fall risk equally well (AUC 0.94) and was the only variable that remained independently associated with high fall risk after adjustment (Table.6), so the dual-task condition did not add discriminative value beyond the single-task TUG in this sample. Self-reported falls were more frequent in the high-risk group (43.4% vs 12.5%, p = 0.024), and TUG-cognitive time discriminated fallers from non-fallers only moderately (AUC 0.75, 95% CI 0.62–0.87).

Clinical Implications

The TUG-cognitive needs only a chair, a stopwatch and a short cognitive task, so it could be added to the routine assessment of ambulatory patients with chronic stroke in our clinical setting. Patients with high dual-task cost may benefit from dual-task training, since a randomized controlled study showed that a dual-task exercise program improved dual-task mobility and reduced falls and fall-related injuries in ambulatory people with chronic stroke and intact cognition (13).

Strengths and limitations

Strengths of this study include standardized procedures, the use of both motor and cognitive costs, and adjustment for key confounders. Several limitations should be noted. First, the cross-sectional design does not allow causal or predictive conclusions. Second, the sample was recruited by convenience sampling from a single center, which limits generalizability. Third, falls were self-reported and may be affected by recall bias. Fourth, only one cognitive task (serial subtraction) was used, and results may differ with other tasks (6). Fifth, patients with severe cognitive impairment or aphasia were excluded. Future prospective studies with larger samples should test whether dual-task performance predicts incident falls. Sixth, the low-risk group was small (n = 16), which limited the number of covariates in the logistic model, and motor DTC was strongly

collinear with single-task TUG time, so its independent effect could not be estimated precisely.

CONCLUSION

In patients with chronic stroke, greater motor and cognitive dual-task costs were associated with poorer functional mobility and higher fall risk, but only cognitive DTC and single-task TUG time remained independently associated with gait speed after adjustment, and motor DTC was not independent of single-task TUG time. The TUG-cognitive discriminated high from low fall risk well, although it did not outperform single-task TUG time in this sample. Prospective studies are needed to confirm whether dual-task performance predicts future falls and whether targeting dual-task deficits reduces fall risk.

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