CORRELATIONS BETWEEN FUNCTIONAL BALANCE AND GAIT PARAMETERS DURING TIMED UP AND GO TEST UNDER DUAL-TASK CONDITIONS AMONG OLDER ADULTS

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Abstract

The combination of physical, cognitive, and sensory challenges can make outdoor walking difficult for older adults. This study aimed to determine whether the gait parameters during the Timed Up and Go (TUG) test under dual-task conditions correlate with the functional balance level. A total of 255 older persons participated in this cross-sectional study. Functional balance was assessed using the Berg Balance Scale (BBS) before the TUG test. The TUG test was conducted under single- and two dual-task conditions (dual-motor and dual-cognitive). The time and number of steps were used to quantify gait parameters. Spearman's rank correlation coefficient was used to assess the relationship among variables. The gait parameters (time and number of steps) of the TUG test were significantly different between task conditions (both, $p = 0.001$). Post hoc analysis with the Wilcoxon signed-rank test showed that the gait parameters in dual-motor and dual-cognitive tasks were significantly longer than in single-task conditions ($p = 0.001$). A strong negative rank correlation was found between the time and the number of steps taken to complete the single task condition and functional balance ($p = 0.001$). There was a low negative correlation between the time taken to complete the dual-motor task and dual-cognitive task conditions and functional balance. These findings suggest that functional balance may be an influential domain of successful dual-task TUG in older adults.

Keywords: Aged, Attention, Gait, Postural Control

Introduction

Falls among community-dwelling older adults are a major issue worldwide, affecting approximately 28% to 35% of individuals aged 65 years and older annually (1). The incidence of falls varies between Asian countries; for example, the incidence rates are 66.7% in Japan (2), 33.1% in Korea (3), and 29% in Indonesia (4). Another study in a Korean rural community reported that 26.1% and 66.9% of the participants had experienced a fall and fear of falling, respectively (5). Furthermore, 13.3% and 32.8% of institutionalized older adults have a high and moderate risk of falling, respectively (6). This issue is expected to increase due to the rising proportion of older adults in the Asian region.

Falls among older adults can have serious consequences, including injury, hospitalization, and even death. In Malaysia, the statistics are alarming, with one in six older adults experiencing at least one fall in 12 months and 43.9% of falls occurring outdoors (7). This highlights the urgent need for effective interventions to reduce the risk of falls among older adults in Malaysia. The reported risk factors for falls among older adults in Malaysia include older age, female gender, neuropathy, balance and gait problems, ethnicity, sleep disturbances, sensory problems, falls, risk-increasing drugs, and anticholinergic medication (8). Older adults at risk of falling may abstain from performing activities that compromise their balance. One of the most

effective ways to reduce the risk of falls among older adults is through early identification of at-risk individuals.

Maintaining balance is crucial in many daily activities, from standing still to more complex tasks such as walking while talking or changing direction (9). As people age, their ability to control balance deteriorates due to changes in various systems, such as the vestibular, visual and central nervous systems (10). Older adults are at a higher risk of falling due to factors such as gait difficulties, impaired balance, visual problems, decreased muscle strength, and limited mobility (11). The risk of falls increases when older adults move around, particularly when walking outside, where they may face obstacles and distractions that require them to change direction and multitask (12).

The Berg Balance Scale (BBS) is commonly utilized in evaluating balance due to its ease of use, minimal materials needed, and inclusion of other tests such as single-leg stance and functional reach (13). Studies have shown that individuals who score below 40 on BBS may need interventions to reduce their risk of falling (14, 15). The Timed Up and Go Test (TUG) is another commonly used assessment that measures balance and mobility in a clinical setting. The TUG test is reliable for evaluating agility, as it involves walking and changing direction. It can also test an older adult's ability to perform complex skills such as turning while walking and carrying objects simultaneously. Research has shown that the time it takes to complete the TUG test can predict falls in older adults living in a community setting (16).

Carrying out the TUG test while performing another task, such as walking while holding a cup or counting backwards, may slow the completion of the task and have a greater impact on older individuals with a history of falls (17) or stroke survivors (18). Dual tasking, also known as multitasking, is the ability to perform two or more tasks simultaneously. However, as individuals age, their ability to perform dual tasks may decline. This is particularly relevant for older adults, as they may experience a decline in cognitive and motor abilities, affecting their ability to perform dual tasks. Additionally, older adults may also experience a decline in working memory, which is essential for holding and manipulating information while performing dual tasks.

Although dual tasking is challenging for older adults due to age-related changes in cognitive and motor abilities, not much research has been done on how balance performance is affected by dual-task TUG in older adults. It is crucial to study these connections to provide evidence to guide the development of interventions for older adults at high risk for falls and to promote functional walking in community settings. Therefore, this study has two specific aims: to determine the effects of dual-task conditions on gait parameters during the TUG test, and to evaluate the relationship between functional balance performance and gait parameters during single- and dual-task conditions (dual-motor and dual-cognitive) during the TUG test among older adults. We hypothesized that functional balance performance would correlate significantly with gait parameters under dual-task conditions.

Materials and Methods

Study design and participants

This prospective cross-sectional study was conducted at a government-funded hospital in Kuala Lumpur, where 255 individuals aged between 60 and 98 were recruited through purposive sampling. In order to be included in the study, participants had to have been under the care of a geriatrician for at least three months, able to walk 6 meters without assistance, hold a glass of water, follow three-step commands, and perform simple arithmetic. Those who used any assistive device and were presented with dementia or peripheral neuropathy from other medical conditions were excluded from the study. Data collection began after obtaining ethics approval and participant consent. The Institutional Review Board of Universiti Teknologi MARA (REC/424/2016) and the Ministry of Health Malaysia (NMRR-19-2585-47819) approved the study protocol.

Outcome measures

The BBS is a widely used tool for functional or measuring performance-oriented balance in older adults (19). It consists of 14 items that are scored on a scale of 0 to 4. These items are designed to assess an individual's ability to perform functional tasks related to balance and mobility, such as standing on one foot, walking and turning around. A score of 0 is given if the participant is unable to perform the task, and a score of 4 is given if the participant can complete the task based on the criterion assigned to it. The maximum total score on the BBS is 56. The BBS is a reliable and valid measure of balance in older adults (20). A previous study has shown that BBS correlates well with laboratory and clinical measures regarding instability and falls in older adults (13).

The TUG test evaluates mobility or dynamic balance (the ability to maintain balance while in motion, such as walking or turning) during daily activities, such as standing up from a chair, walking and sitting back down in a timed manner. The test is conducted by having the participants sit with their backs against a chair, then after hearing the word 'go', stand up, walk a 3-m pathway, turn around on a mark, then return to the chair and sit down again. The chair used in the TUG test has specific measurements of 44 cm for seat height, 49 cm for width, and 64 cm for armrest height. This ensures that the test is standardized and consistent for all participants.

The entire process is timed, and the time it takes for the participant to complete the test is recorded. The TUG test is a simple and reliable measure of dynamic balance and has been used in various settings, including hospitals, rehabilitation centres and long-term care facilities. The results of the TUG test can be used to identify individuals

at risk of falling and to guide interventions to improve their balance and mobility (14).

Testing procedures

We obtained our primary outcomes, which were the time and number of steps taken to complete the TUG test. The calibrated digital stopwatch was used to measure the time the participant took to complete each task, while the digital video camera was used to record the number of steps taken. This allowed for more accurate and precise measurement of the gait parameters (as shown in Figure 1). The scores were analyzed by comparing the average time and number of steps taken in each condition. A 5-minute rest period was provided between tests to alleviate any fatigue effects. Additionally, gait parameters such as time (in seconds) and the number of steps were recorded across dual-task conditions during the TUG (9). The final score was the average of three attempts.

The single-task TUG involved participants completing the TUG test without any additional task. They were instructed to sit comfortably in a chair, stand up and walk past a 3-m mark after hearing the word "go", then return to the chair and sit down without assistance. In the dual-motor task TUG, participants were asked to perform the TUG test while holding a cup of water, trying not to spill it, or else the trial would have to be repeated. For the dual-cognitive task TUG, participants were instructed to perform the TUG test while counting backwards by 3 from a random number between 80 and 99. Any errors in counting would result in the trial having to be repeated. The participants were encouraged to give their best performance in both tasks to determine their natural strategy in dealing with divided attention.

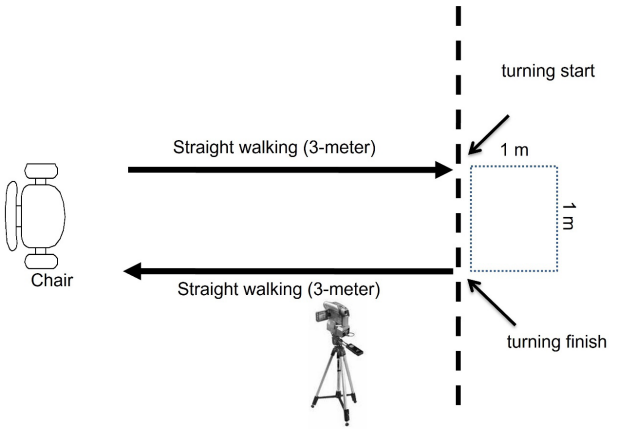

Figure 1: Diagrammatic presentation of the experimental procedure

Statistical analysis

All analyses were conducted using IBM SPSS version 26.0 for Windows, with a statistical significance level of $p<0.05$. The Friedman test was used to examine the effect of dual-task conditions on the TUG test completion time and the number of steps for older adults. Following this, a Wilcoxon signed-rank test was used for post-hoc analysis. Additionally, Spearman's rank-order correlation coefficients were calculated to establish the relationship between functional balance and gait parameters (number of steps and time taken) in single and dual-task conditions.

Results

Demographic characteristics of participants

Table 1 shows the demographic and disability characteristics of the participants. A total of 127 male and 128 female older adults participated in this study.

Table 1: Characteristics of the participants (N = 255)

Characteristic	Mean ± SD	Range
Age (years)	74.01 ± 8.81	60 – 98
Functional Balance (BBS) (Max score: 56)	43.56 ± 68.2	44 – 56
Single Task TUG (second)	14.0 ± 4.75	6.1 – 27.0
Dual Motor Task TUG (second)	27.5 ± 7.99	8.9 – 55.7
Dual Cognitive Task TUG (second)	39.9 ± 9.7	15 – 60.6

Abbreviations: BBS Berg Balance Scale; TUG Timed Up and Go test; SD Standard Deviation

Effects of dual-task conditions on gait parameters

The Friedman's test shows a statistically significant increase in the time taken to complete the TUG ($p = 0.001$). Post-hoc analysis with Wilcoxon signed-rank test shows that TUG time in dual-motor and dual-cognitive tasks are significantly longer than under single-task conditions ($p = 0.001$). The TUG time is significantly longer in the dual-cognitive than under the dual-motor task condition ($p = 0.001$). Concerning the performance of the dual-motor task, the participants successively stabilized the cup, except for a participant who spilled 1.8 g of water from the cup in 1 of 3 trials. The Friedman's test shows a statistically significant increase in the number of steps to complete the TUG ($p = 0.001$). Post-hoc analysis with Wilcoxon signed-rank test shows that the number of steps in dual-motor and dual-cognitive TUG tests are significantly greater than that under the single-task condition ($p = 0.001$). A significantly greater number of steps was observed under the dual-cognitive than under the dual-motor task condition ($p = 0.001$).

Correlation between functional balance (BBS) and gait parameters

A strong negative rank correlation was found between the time taken to complete the single-task condition and BBS ($r_s = -0.844$; $p = 0.001$). A low negative rank correlation was found between the time taken to complete the dual-motor task conditions and BBS ($r_s = -0.463$; $p = 0.001$). In addition, a low negative rank correlation was detected between the time taken to complete the dual-cognitive task conditions

and functional balance (r_s= −0.281; p = 0.001). A strong negative rank correlation was found between the number of steps to complete the single-task condition (r_s= −0.814; p = 0.001). There was a low negative rank correlation among the number of steps to complete the dual-motor task condition (r_s= −0.501; p = 0.001), dual-cognitive task condition (r_s=−0.409; p = 0.001), and functional balance.

Discussion

This study investigates how dual-task conditions (dual-motor and dual-cognitive) affect gait parameters during the TUG test in older adults. We found that performing dual tasks led to a decrease in gait parameters. Additionally, we discovered a strong correlation between functional balance and gait parameters during the TUG test in all single, dual-motor, and dual-cognitive task conditions.

Our findings indicate that dual-motor and dual-cognitive tasks resulted in significantly longer TUG times than single tasks. The dual-motor task appeared to be particularly affected by age, while the dual-cognitive task was thought to be impacted by the level of focus and attention. Previous studies have also reported changes in gait patterns in older adults with and without dementia when performing tasks that require simultaneous attention (21, 22). Early onset of cognitive decline and neurodegenerative diseases can lead to significant interference when performing simple cognitive and motor tasks simultaneously (23). However, despite the accuracy achieved by the current specialized systems there are constraints that limit quantitative gait analysis, for instance, the cost of the equipment, the limited access for many people and the lack of solutions to consistently monitor gait on a continuous basis. In this paper, two low-cost systems for quantitative gait analysis are presented, a wearable inertial system that relies on two wireless acceleration sensors mounted on the ankles; and a passive vision-based system that externally estimates the measurements through a structured light sensor and 3D point-cloud processing. Both systems are compared with a reference clinical instrument using an experimental protocol focused on the feasibility of estimating temporal gait parameters over two groups of healthy adults (five elders and five young subjects), eventually decreasing the gait velocity (24). Furthermore, a decrease in walking speed can be interpreted as an implicit strategy to avoid falling and losing gait stability (25). This study also shows a significantly greater number of steps in the dual-cognitive than in the dual-motor task condition. The arithmetic task may cause a higher gait instability (26). This finding is supported by a previous study that found greater gait instability while counting backwards compared to counting forward as when walking down a steeper gradient while performing a concurrent cognitive task, would demand gait adaptation beyond those required for walking under low-challenge conditions (27). Thirteen healthy young individuals participated in a study where they walked on a treadmill at their self-selected speed. The study included different inclinations of the treadmill, specifically 0%, -5%, and -10%.

The current study revealed that incorporating a cognitive task into the TUG test improves its ability to accurately identify individuals at high or low risk of falling (28). This study also showed that adding cognitive processing to the TUG decreased the automaticity of gait. This is due to interference from dual tasks, where the demands of secondary tasks exceed the available attentional resources, reducing the performance for one or both tasks. The dual-cognitive TUG may be more useful as a multifactorial fall risk assessment component, including other variables, such as the history of falls, disease severity, and freezing of gait (29). These factors have strong predictive qualities for the risk in older adults. The differences in the discriminative abilities of the dual-cognitive and motor TUG may be partly attributed to the complexity of the task (30, 31). The difficulty of the secondary task influences the pattern and speed of gait in older people. The secondary tasks used in this study are commonly used in clinical practice as standard additions to the dual-task TUG.

The current study also discovered a link between a longer time and more steps taken during the TUG test and lower BBS scores. This is consistent with findings from a previous study that revealed a negative correlation between BBS and TUG test (32). Furthermore, the TUG test under single and dual-task conditions can lead to variations in walking performance (33). Additionally, a strong correlation between BBS and TUG suggests that TUG could be an effective alternative for measuring balance (9, 34). The BBS is a measure of balance that primarily assesses stability while sitting and standing, both statically and dynamically. On the contrary, the TUG test evaluates balance during movement, such as walking and turning, and includes elements of gait and coordination in its assessment (34). Although the complexity of the tasks may have affected the test results in the current study, we are confident of the validity of our interpretation due to the strong reported outcomes.

This study highlighted a few limitations that need to be addressed in future research. One limitation is the lack of consensus on which additional task is most effective in causing interference in older populations. Another limitation is the lack of established instructions or guidelines for task prioritization in the TUG test. Further standardization of dual-task gait analysis is needed to improve comparability between gait laboratories and studies. Furthermore, future research should focus on defining the appropriate prioritization of tasks, instructions, standards, and reference values for the TUG. Comparing the complexities of different secondary tasks in the dual TUG test may provide additional information.

Conclusion

Older adults demonstrate the deterioration of gait parameters, including a longer time and more steps to complete the TUG. The deficits are exaggerated under dual-task conditions. The dual-motor and cognitive TUG are related to the time taken and the number of steps.

More difficult tasks require more time and steps because the participant must be more careful to avoid falling and requires more attention during each task.

Acknowledgement

The authors thank the Universiti Teknologi MARA for funding the research project through the Geran Insentif Penyeliaan [600-RMC/GIP 5/3 (058/2022)]

Competing interests

The authors declare that they have no competing interests.

Ethical clearance

We obtained approval from the Ministry of Health Malaysia (MOH), registered under NMRR-19-2585-47819.

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