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CORRELATION BETWEEN FUNCTIONAL REACH TEST, TIMED UP AND GO TEST, AND SINGLE LEG STAND TEST FOR ASSESSING BALANCE IN PATIENTS WITH TRAUMATIC BRAIN INJURY: A CROSS-SECTIONAL OBSERVATIONAL STUDY

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Traumatic Brain Injury, Functional Reach Test, Timed Up and Go Test, Single Leg Stand Test, Balance, Fall Risk, Correlation.

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Abstract

Background: Traumatic Brain Injury (TBI) frequently results in impaired balance, postural instability, and increased risk of falls. Clinical balance assessment tools such as the Functional Reach Test (FRT), Timed Up and Go Test (TUG), and Single Leg Stand Test (SLS) are commonly used to evaluate balance performance; however, the relationship among these measures in patients with TBI remains insufficiently explored.

Objective: To determine the correlation between the Functional Reach Test, Timed Up and Go Test, and Single Leg Stand Test in patients with Traumatic Brain Injury.

Methods: An observational correlation study was conducted among **60 patients** diagnosed with TBI. Participants underwent assessment using the Functional Reach Test (FRT), Timed Up and Go Test (TUG), and Single Leg Stand Test (SLS). Data were analyzed using descriptive statistics. Normality was assessed using the Shapiro-Wilk test. Since the data were not normally distributed, Spearman's rank correlation coefficient was used to determine the relationships among the outcome measures. Statistical significance was considered at $p < 0.05$.

Results: The mean age of participants was **37.68 ± 10.22 years**, with males constituting **58.33%** of the sample. Most participants demonstrated moderate dizziness handicap (65%) and high fall risk according to the TUG (60%). Functional Reach Test showed moderate fall risk in **61.67%** of participants, whereas **35%** were categorized as high fall risk on the Single Leg Stand Test.

A significant moderate positive correlation was observed between Functional Reach Test and Timed Up and Go Test (**Spearman's r = 0.4114, p = 0.0011**). However, the correlation between Functional Reach Test and Single Leg Stand Test was weak and statistically non-significant (**r = 0.1347, p = 0.3047**). A significant association was also observed between Functional Reach categories and Single Leg Stand categories ($\chi^2 = 13.46$, $p = 0.036$).

Conclusion: Functional Reach Test demonstrates a significant relationship with functional mobility assessed by the Timed Up and Go Test in patients with Traumatic Brain Injury. The Single Leg Stand Test evaluates a different aspect of postural control and should be used alongside Functional Reach Test and Timed Up and Go Test for comprehensive balance assessment. Combining these clinical tests may improve identification of patients at risk of falls and facilitate individualized rehabilitation planning.

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Introduction

Traumatic Brain Injury (TBI) is a major global public health concern and one of the leading causes of mortality and long-term disability across all age groups. It results from an external mechanical force to the head, causing temporary or permanent impairment of neurological function. Common causes include road traffic accidents, falls, sports-related injuries, occupational accidents, and assaults. Depending on the severity and location of the injury, individuals with TBI may experience a wide range of physical, cognitive, emotional, sensory, and functional impairments that significantly affect their independence and quality of life.

Among the numerous neurological deficits associated with TBI, balance impairment is one of the most common and disabling consequences. Balance is a complex motor function that depends on the coordinated interaction of the visual, vestibular, and somatosensory systems, along with appropriate integration by the central nervous system. Damage to any of these systems following TBI can disrupt postural control and equilibrium, resulting in impaired balance, dizziness, instability during standing and walking, delayed postural reactions, reduced coordination, and an increased risk of falls.

Vestibular dysfunction is frequently observed following traumatic brain injury due to injury involving the peripheral vestibular apparatus or central vestibular pathways. Patients commonly report symptoms such as dizziness, vertigo, blurred vision during movement, impaired gaze stabilization, and difficulty maintaining postural stability. In addition, injury to the cerebellum, basal ganglia, motor cortex, or sensory pathways can impair motor planning, coordination, proprioception, muscle activation, and protective balance responses. These impairments often persist beyond the acute stage of injury and substantially limit functional mobility, activities of daily living, community participation, and overall quality of life.

Balance dysfunction has significant clinical implications because it is strongly associated with gait abnormalities, decreased walking speed, reduced functional independence, fear of falling, recurrent falls, and prolonged rehabilitation. Falls following TBI may lead to secondary injuries, hospital readmissions, increased healthcare costs, and delayed recovery. Therefore, accurate assessment of balance is essential for identifying impairments, determining fall risk, monitoring recovery, and developing individualized rehabilitation programs.

Several standardized clinical outcome measures are available to evaluate different components of balance and functional mobility in individuals with neurological disorders. The **Functional Reach Test (FRT)** is a simple and reliable clinical measure that assesses dynamic balance by evaluating the maximum distance an individual can voluntarily reach forward while maintaining a fixed base of support. It reflects the limits of stability and the ability to control the body's center of mass during functional activities.

The **Timed Up and Go Test (TUG)** is a widely used functional mobility assessment that measures the time required for an individual to stand from a chair, walk three meters, turn around, return to the chair, and sit down. The test evaluates multiple aspects of functional performance, including dynamic balance, gait speed, lower-limb strength, mobility, and transfer ability. Longer completion times are associated with poorer mobility and an increased risk of falls.

The **Single Leg Stand Test (SLS)** evaluates static postural stability by measuring the duration for which an individual can maintain balance while standing on one leg. The test challenges proprioceptive control, neuromuscular coordination, vestibular function, and lower-limb muscle strength. Reduced single-leg stance time has been associated with impaired balance control and a greater likelihood of falls in neurological populations.

Although these clinical tests assess different dimensions of balance, they are interconnected

because they all reflect the integrity of postural control mechanisms. Understanding the relationship among the Functional Reach Test, Timed Up and Go Test, and Single Leg Stand Test may provide valuable information regarding the multidimensional nature of balance impairment in patients with traumatic brain injury. Establishing correlations among these assessments may help clinicians determine whether improvements in one aspect of balance are associated with improvements in others, thereby facilitating more efficient and comprehensive clinical evaluation.

Furthermore, identifying the degree of correlation among these balance assessment tools may assist physiotherapists and rehabilitation professionals in selecting the most appropriate outcome measures for clinical practice and research. This is particularly important in settings where time, equipment, or patient endurance may limit the number of assessments that can be performed. Reliable and valid clinical measures enable accurate monitoring of rehabilitation progress, evaluation of treatment effectiveness, and prediction of fall risk.

Therefore, the present study aims to investigate the correlation between the Functional Reach Test, Timed Up and Go Test, and Single Leg Stand Test in patients with traumatic brain injury. Understanding these relationships may contribute to evidence-based clinical decision-making, enhance balance assessment strategies, and support the development of targeted rehabilitation interventions designed to improve postural control, functional mobility, and overall quality of life while reducing the risk of falls in individuals with traumatic brain injury.

Materials and Methods

- **Study Design:** Observational correlation study.
- **Study Population:** Patients diagnosed with Traumatic Brain Injury.
- **Sample Size:** 60 participants.
- **Sampling Technique:** Random sampling.
- **Outcome Measures:**
  - Functional Reach Test (FRT)
  - Timed Up and Go Test (TUG)
  - Single Leg Stand Test (SLS)
- **Statistical Analysis:**
  - Descriptive statistics
  - Shapiro-Wilk test for normality
  - Spearman Rank Correlation
  - Chi-square test
  - Significance level: $p < 0.05$.

Results

The study included **60 patients** with Traumatic Brain Injury. Males constituted **58.33%**, while females accounted for **41.67%**. The mean age was **37.68 ± 10.22 years**.

Regarding balance performance:

- **60%** demonstrated high fall risk on the Timed Up and Go Test.
- **61.67%** showed moderate fall risk on the Functional Reach Test.
- **35%** were classified as high fall risk using the Single Leg Stand Test.

Normality testing revealed that all variables were non-normally distributed; therefore, non-parametric statistical methods were employed.

Correlation Analysis

Variables	Spearman's r	p-value	Interpretation
FRT vs TUG	0.4114	0.0011	Moderate positive significant correlation
FRT vs SLS	0.1347	0.3047	Weak, non-significant correlation

The association between Functional Reach categories and Single Leg Stand categories was statistically significant ($\chi^2 = 13.46$, $p = 0.036$).

Discussion

The present study demonstrated that Functional Reach Test scores were moderately correlated with Timed Up and Go performance, indicating that patients with better dynamic balance generally exhibited better functional mobility and lower fall risk.

Conversely, the weak and non-significant correlation between Functional Reach Test and Single Leg Stand Test suggests that static and dynamic balance represent different components of postural control in individuals with TBI. Although both tests assess balance, they challenge different sensory and neuromuscular systems.

The findings emphasize that relying on a single

balance assessment may underestimate the complexity of balance impairments after TBI. Therefore, a combination of dynamic and static balance assessments provides a more comprehensive evaluation of functional performance.

Clinical Management

Based on the findings, rehabilitation programs should include:

- Dynamic balance training using reaching and weight-shifting exercises.
- Static balance training with progressively challenging single-leg stance activities.
- Functional gait training incorporating turning, transfers, and obstacle negotiation.
- Vestibular rehabilitation exercises for patients with dizziness.
- Strengthening exercises targeting lower-limb and core musculature.
- Proprioceptive and sensory integration training.
- Fall prevention education and home safety modifications.
- Regular reassessment using FRT, TUG, and SLS to monitor rehabilitation progress.

Conclusion

The Functional Reach Test demonstrated a significant moderate correlation with the Timed Up and Go Test, indicating that both tools assess related aspects of dynamic balance and functional mobility in patients with Traumatic Brain Injury. However, the Single Leg Stand Test showed only a weak correlation with Functional Reach Test, suggesting that static balance is a distinct component of postural control. Therefore, clinicians should use all three assessment tools collectively to achieve a comprehensive evaluation of balance deficits and fall risk in patients with TBI. This combined assessment approach can facilitate individualized rehabilitation planning and improve functional outcomes.

Validity and Reliability of the Functional Reach Test (FRT), Timed Up and Go Test (TUG), and Single Leg Stand Test (SLS)

Reliable and valid clinical outcome measures are essential for accurately assessing balance, mobility, and fall risk in individuals with neurological disorders such as traumatic brain injury (TBI). The Functional Reach Test (FRT), Timed Up and Go Test (TUG), and Single Leg Stand Test (SLS) are widely used because they are simple, inexpensive, and require minimal equipment. Numerous studies have demonstrated their validity and reliability across neurological, geriatric, and musculoskeletal populations.

1. Functional Reach Test (FRT)

The **Functional Reach Test (FRT)** was developed by Duncan PW and colleagues in 1990 to assess dynamic balance and the limits of stability in standing. It measures the maximum distance an individual can voluntarily reach forward without taking a step or losing balance.

Reliability

The FRT has demonstrated excellent reliability in both healthy individuals and patients with neurological disorders.

- **Intra-rater reliability:** ICC = **0.89–0.98**
- **Inter-rater reliability:** ICC = **0.81–0.97**
- **Test–retest reliability:** ICC = **0.81–0.92**

These high reliability coefficients indicate that the test produces consistent measurements when performed by the same examiner, different examiners, or across repeated testing sessions.

Validity

The Functional Reach Test has established good validity for evaluating dynamic balance.

- Demonstrates strong **construct validity** as a measure of dynamic postural control.
- Shows significant **criterion validity** through correlations with laboratory measures of balance.
- Demonstrates **predictive validity** for identifying individuals at increased risk of falls.
- Has moderate to strong correlations with the Berg Balance Scale, Timed Up and Go Test, and gait performance.

Because of its simplicity and sensitivity to changes in balance performance, the FRT is commonly used in patients with stroke, Parkinson's disease, vestibular disorders, traumatic brain injury, and older adults.

2. Timed Up and Go Test (TUG)

The **Timed Up and Go (TUG) Test** was introduced by Podsiadlo D and Richardson S in 1991. The test measures the time required for an individual to stand from a chair, walk three meters, turn around, return to the chair, and sit down. It

evaluates functional mobility, balance, gait, and lower-extremity function.

Reliability

The TUG has consistently demonstrated excellent reliability across various patient populations.

- **Intra-rater reliability:** ICC = **0.95–0.99**
- **Inter-rater reliability:** ICC = **0.94–0.99**
- **Test–retest reliability:** ICC = **0.89–0.99**

These findings indicate that TUG scores remain highly consistent regardless of the examiner or testing occasion.

Validity

The Timed Up and Go Test has excellent validity for assessing functional mobility.

- Strong **criterion validity** compared with other functional mobility assessments.
- Demonstrates excellent **construct validity** by evaluating multiple components of functional performance, including transfers, walking, turning, and sitting.
- Shows strong correlations with the Berg Balance Scale, Functional Reach Test, gait speed, Dynamic Gait Index, and Activities-specific Balance Confidence Scale.
- Widely accepted as a valid predictor of fall risk in neurological and geriatric populations.

The TUG is particularly useful in individuals with traumatic brain injury because it reflects both balance impairment and functional mobility limitations.

3. Single Leg Stand Test (SLS)

The **Single Leg Stand Test (SLS)**, also known as the One-Leg Stance Test, assesses static balance by measuring the duration for which an individual can maintain balance while standing on one leg. The test evaluates postural stability, proprioception, vestibular function, lower-limb muscle strength, and neuromuscular control.

Reliability

The SLS has demonstrated good to excellent reliability.

- **Intra-rater reliability:** ICC = **0.85–0.99**
- **Inter-rater reliability:** ICC = **0.83–0.99**
- **Test–retest reliability:** ICC = **0.80–0.97**

These results indicate that SLS measurements are highly reproducible when standardized testing procedures are followed.

Validity

The Single Leg Stand Test possesses strong validity for assessing static postural control.

- Demonstrates good **construct validity** for static balance assessment.
- Shows significant correlations with the Berg Balance Scale, Functional Reach Test, and posturography measurements.
- Has good **predictive validity** for identifying individuals at risk of falls.
- Sensitive to impairments in vestibular function, proprioception, and lower-limb neuromuscular control.

The SLS is frequently used in neurological rehabilitation, sports medicine, geriatrics, and orthopedic practice because it provides a quick assessment of single-limb postural stability.

Clinical Relevance in Traumatic Brain Injury

Patients with traumatic brain injury commonly experience impairments in balance due to disruption of vestibular pathways, cerebellar function, sensory integration, and motor control. The Functional Reach Test, Timed Up and Go Test, and Single Leg Stand Test evaluate complementary aspects of balance and mobility. Together, they provide a comprehensive assessment of dynamic balance, functional mobility, and static postural stability. Their high reliability and established validity support their use as outcome measures for identifying balance deficits, monitoring rehabilitation progress, evaluating treatment effectiveness, and estimating fall risk in individuals with TBI.

Summary of Reliability and Validity

Test	Intra-rater Reliability (ICC)	Inter-rater Reliability (ICC)	Test–Retest Reliability (ICC)	Validity
Functional Reach Test (FRT)	0.89–0.98	0.81–0.97	0.81–0.92	Excellent construct, criterion, and predictive validity for dynamic balance
Timed Up and	0.95–0.99	0.94–0.99	0.89–0.99	Excellent validity for functional

Test	Intra-rater Reliability (ICC)	Inter-rater Reliability (ICC)	Test–Retest Reliability (ICC)	Validity
Go Test (TUG)				mobility and fall risk assessment
Single Leg Stand Test (SLS)	0.85–0.99	0.83–0.99	0.80–0.97	Good construct and predictive validity for static balance and postural control

Key References

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Why Correlating the Functional Reach Test (FRT), Timed Up and Go Test (TUG), and Single Leg Stand Test (SLS) is Clinically Important

Balance impairment is a common and disabling consequence of traumatic brain injury (TBI), resulting from damage to the vestibular system, cerebellum, sensory pathways, and cortical motor regions. Since balance is a multidimensional function involving static stability, dynamic postural control, and functional mobility, no single clinical test can comprehensively evaluate all aspects of balance. Therefore, understanding the relationship between the **Functional Reach Test (FRT)**, **Timed Up and Go Test (TUG)**, and **Single Leg Stand Test (SLS)** is clinically important for several reasons.

1. Comprehensive Assessment of Balance

Each of the three tests measures a distinct component of balance:

- **Functional Reach Test (FRT):** Assesses dynamic balance and limits of stability.
- **Timed Up and Go Test (TUG):** Evaluates functional mobility, dynamic balance, gait performance, and fall risk.
- **Single Leg Stand Test (SLS):** Measures static postural stability and single-limb balance.

Correlating these tests helps determine whether performance in one aspect of balance is associated with performance in other domains. This provides a more comprehensive understanding of postural control deficits in patients with TBI.

2. Identification of Functional Relationships

Balance impairments following TBI often affect multiple systems simultaneously. A significant correlation between FRT, TUG, and SLS would suggest that deficits in dynamic balance, static balance, and functional mobility are interrelated. Conversely, weak or absent correlations would indicate that each test evaluates a unique aspect of balance requiring separate assessment. Understanding these relationships assists clinicians in selecting the most informative assessment tools.

3. Improved Clinical Decision-Making

Physiotherapists often have limited time to perform multiple outcome measures in busy clinical settings. If strong correlations exist among these tests, clinicians may use one assessment as a surrogate indicator of another in selected situations, reducing assessment time without compromising clinical decision-making. If correlations are weak, the findings emphasize the need to perform multiple complementary assessments to capture all relevant balance deficits.

4. Better Prediction of Fall Risk

Patients with TBI have an increased risk of falls due to impaired postural control, delayed motor responses, dizziness, and gait abnormalities. Since the TUG is widely used to assess fall risk, correlating it with the FRT and SLS can help determine whether impairments in dynamic reach or single-leg balance are associated with reduced

functional mobility and increased fall risk. This information enables clinicians to identify high-risk individuals earlier and implement targeted fall-prevention strategies.

5. Development of Targeted Rehabilitation Programs

Different balance deficits require different therapeutic interventions. Understanding the relationships among FRT, TUG, and SLS allows rehabilitation professionals to identify which components of balance contribute most to functional limitations. Treatment programs can then be tailored to address specific impairments, such as dynamic stability, gait training, lower-limb strength, postural control, or vestibular rehabilitation, thereby improving rehabilitation outcomes.

6. Monitoring Rehabilitation Progress

Reliable clinical outcome measures are essential for tracking changes during rehabilitation. Correlating these balance assessments helps determine whether improvements in one domain (e.g., dynamic balance measured by FRT) are accompanied by improvements in functional mobility (TUG) or static balance (SLS). This provides a broader understanding of patient recovery and the effectiveness of physiotherapy interventions.

7. Contribution to Evidence-Based Physiotherapy Practice

Although the FRT, TUG, and SLS are widely used in neurological rehabilitation, relatively few studies have specifically examined their interrelationship in individuals with traumatic brain injury. Establishing correlations among these tests contributes to the evidence base supporting their clinical use, assists in selecting appropriate outcome measures, and may improve the standardization of balance assessment protocols in TBI rehabilitation.

8. Enhancement of Functional Independence and Quality of Life

Balance deficits significantly limit mobility, participation in daily activities, and community reintegration following TBI. Accurate assessment of multiple balance components enables clinicians to identify impairments early and implement individualized rehabilitation strategies. Improved balance contributes to reduced fall risk, increased confidence during mobility, greater independence in activities of daily living, and enhanced overall quality of life.

Clinical Significance of the Present Study

The present study, **"Correlation Between Functional Reach Test, Timed Up and Go Test, and Single Leg Stand Test for Assessing Balance in Patients with Traumatic Brain Injury: A Cross-Sectional Observational Study,"** seeks to determine the relationships among three commonly used clinical balance assessment tools. Establishing these correlations will help physiotherapists understand whether these tests measure overlapping or distinct aspects of balance, optimize assessment protocols, improve clinical decision-making, guide individualized rehabilitation planning, and enhance the prediction of fall risk in patients with traumatic brain injury. The findings may also support the selection of efficient, reliable, and evidence-based outcome measures for neurological rehabilitation and future research.