*Original Article*

# The Association of Trunk Control and Postural Stability with Functional Ambulation in Stroke Patients: A Longitudinal Study

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## ABSTRACT

**Background:** Post-stroke ambulation is a crucial rehabilitation milestone, but it is often hindered by sensory impairments and postural instability. Comprehensive assessments of hip flexion strength, trunk control, and postural stability are essential for developing effective rehabilitation strategies. This study investigates the relationship between these factors with functional ambulation at one, six, and twelve weeks post-stroke, aiming to address gaps identified in previous researches.

**Methods:** This longitudinal study was conducted at Hayatabad Medical Complex Peshawar from January to October 2023. A total of 102 patients with acute stroke were selected through non-probability convenience sampling. Patients were followed for twelve weeks. Cognitively stable patients with age >18 years and recent onset of ischemic or hemorrhagic stroke were included in this study. All the eligible patients were assessed using the Trunk Impairment Scale (TIS), the Functional Ambulatory Category (FAC), and the Postural Assessment Scale for Stroke (PASS). GraphPad Prism version (9.5) was utilized for data analysis.

**Results:** Patients with minor strokes significantly improved TIS scores, increasing from 14.63 at week 1 to 19.43 by week 12 ($p<0.01$). The FAC and PASS showed substantial improvements from baseline to week 12 ($p<0.01$). Correlation analysis indicated a strong positive relationship at week 12 between FAC and TIS ($r=0.72$, $p<0.05$) and PASS ($r=0.77$, $p<0.05$), and a moderate correlation with hip flexor strength ($r=0.55$, $p>0.05$).

**Conclusion:** Our findings reveal the critical connections between postural control, trunk performance, and functional ambulation during stroke recovery. The strong correlations between postural control, trunk performance and independent walking emphasize the importance of targeting trunk stability in early rehabilitation efforts to enhance patient independence.

**Keywords:** Cerebrovascular Accident, Functional Gain, Functional Independence Measure, Rehabilitation Stroke Assessment.

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## INTRODUCTION

Stroke is the second leading cause of disability and mortality worldwide[1]. While the overall incidence of stroke has declined in the 2010s compared to the 1990s, recent estimates indicate a rising prevalence among younger individuals (under 50 years of age), highlighting a shifting demographic trend that warrants further attention[2]. A recent study conducted in the Khyber Pakhtunkhwa province of Pakistan reported a stroke prevalence of 1.2% (1,200 cases per 100,000 population), highlighting a significant burden of the disease in the region[3]. Musculoskeletal complications are a significant contributing factor that hinders the recovery process, often prolonging rehabilitation and impacting overall functional outcomes[4]. Other contributing factors include trunk performance, as well as both static and dynamic balance. Trunk control is crucial, as it influences balance and functional abilities, making it challenging for individuals to regain pre-stroke mobility levels[5].

The loss of trunk function can lead to difficulties in maintaining posture, executing selective movements, and adjusting balance, thereby impeding overall rehabilitation[6]. The upper motor neuron lesions in stroke lead to dysfunctions, including impaired selective motor control, muscle weakness, proprioceptive issues, and spasticity, contributing to abnormal gait patterns[7]. The majority of stroke patients regain some ability to walk post-stroke, but a significant number of sensory impairments disrupt motor pathways, necessitating effective rehabilitation programs to restore function[8]. Approximately 50% of stroke patients struggle to walk independently after rehabilitation, underscoring the need to focus on key factors such as trunk control and hip extension, which are essential for improving gait and overall functional outcomes[9-10].

A recent study introduced the Time to walk independently after stroke (TWIST algorithm), which found a strong association between discharge from the hospital, hip muscle strength, trunk performance, and functional ambulation[11]. Their findings indicated that patients demonstrating better trunk control and hip muscle strength were likelier to achieve independent ambulation post-stroke[12]. However, the TWIST study did not incorporate the Postural Assessment Scale, which has been shown in previous research to have a cutoff score of 12.5 at the time of discharge, serving as a good predictor for independent ambulation[13-14]. This gap highlights the importance of considering multiple assessment tools to predict better walking independence after stroke.

Evaluating the postural stability alongside evaluations of trunk control and hip muscle strength may provide a more comprehensive understanding of the factors influencing ambulation post-stroke. This multifaceted approach can inform targeted rehabilitation strategies, ultimately enhancing recovery outcomes for stroke survivors.

## METHODOLOGY

### *Study Design*

This longitudinal study was conducted in the physical therapy department of Hayatabad Medical Complex, Peshawar, Pakistan between January and October 2023. A total of 102 acute stroke patients were prospectively followed for 12 weeks using non-probability convenience sampling.

### *Eligibility of Participants*

The inclusion criteria for this study were as follows:

- Stroke patients aged 8 years,
- Presented with lower limb muscle weakness (<100 on the Motricity Index),
- Acute ischemic stroke or intracerebral hemorrhage who presented during the first-week post-stroke; and
- Mini-Mental Status Examination (MMSE) a score of ≥24.

Exclusion criteria was;

- Stroke patients with prior muscular weakness unrelated to stroke,
- Those who required supervision and support for ambulation before the recent onset of stroke,
- Individuals with bilateral or cerebellar strokes, and patients with stroke severity score >20 on the National Institute of Health Stroke Scale (NIHSS).

### *Outcome Measures*

- **The Trunk Impairment Scale (TIS)**, a 23-item tool that evaluates static and dynamic trunk control, assesses patients' trunk performance. The TIS is a valid and reliable tool (ICC=0.97)[15-17].

- **The Lower Limb Motricity Index (MI)** is a tool with a maximum of 100 scores for assessing lower limb strength. This tool assesses hip flexor, Knee extensor, and dorsiflex strength; each component carries 33 score[18].

- **Medical Research Council – Manual Muscle testing (MRC-MMT)** assesses muscle strength on a scale of 0 to 5, with Zero indicating no muscular flicker and 5 indicating the ability to complete the range of motion against maximum resistance. The test-retest reliability of MMT is ICC= 0.92[19-20].

- **Functional Ambulatory Category (FAC)** is a clinical scale used to assess functional ambulation on a scale of 1 to 5, with 1 indicating that the patient cannot walk or needs support from two or more people and 5 indicating the ability to walk independently anywhere. This tool is reliable for evaluating functional ambulation. (ICC= 0.98)[21].

- **The Postural Assessment Scale for Stroke (PASS)**, a 12-item performance based scale, was used to evaluate postural stability. Each item is scored from 0 to 3, with a maximum score of 36. A recent study identified a cutoff score of 12.5 at the time of hospital discharge post-stroke as a strong predictor of independent ambulation. The PASS demonstrated excellent construct validity (r=0.80)[22-23].

### *Data Collection Procedure*

At baseline, stroke severity and cognitive stability were evaluated, followed by assessing primary outcome measures i.e. TIS, MI, and FAC at baseline, 6 and 12 weeks. All data were meticulously recorded and later used for analysis.

### *Ethical Considerations*

The study strictly adhered to the Helsinki Declaration. Participants provided written informed consent, and the study adhered to STROBE guidelines, ensuring patient confidentiality and maintaining ethical integrity throughout the research process.

### *Data Analysis*

Data was analyzed utilizing GraphPad Prism (version 9.5.1) a statistical and scientific data analysis software developed by GraphPad Software, Inc, widely used for biomedical research to perform advanced statistical tests, generate publication-quality graphs, and analyze experimental data. Descriptive statistics were presented as mean, standard deviation, number, and percentage. Repeated measure one-way ANOVA was used to find the mean differences over time. Pearson correlation or Spearman rank correlation coefficient was utilized to ascertain the relationship between dependent and independent variables, depending on the data normality established using the Shapiro-Wilk test. The magnitude of the relationship was categorized as per the already established criterion: a relationship between 0-0.3 indicates no or weak correlation, 0.3- 0.5 indicates a mild correlation, 0.5-0.7 indicates a moderate correlation and 0.7-0.99 indicates a strong correlation. The critical alpha value was set at p=<0.05.

## RESULTS

### *Demographic Characteristics*

The mean age of the participants was 48.15 + 4.48, the total number of males was 55 (53.9%), and 47 (46.1%) were female. Patients were stratified into two groups based on the NIHSS score. A total of 72.5% were categorized as Moderate stroke, and 28.5% were having minor stroke (Table-1).

**Table-1. Demographic Characteristics**

| **Variables** | **Values** | |
|---|---|---|
| **Age** (Mean±SD) | 48.15±4.48 | n (%) |
| **Stroke Severity (NIHSS)** | Minor Stroke | 28 (27.5%) |
| | Moderate Stroke | 74 (72.5%) |
| **Gender** | Male | 55 (53.9%) |
| | Female | 47 (46.1%) |
| **BMI** | Normal | 35(34.3%) |
| | Overweight | 44 (43.2%) |
| | Obese | 23 (22.5%) |
| **Type of Stroke** | Ischemic Stroke | 84 (82.5%) |
| | Intracerebral Hemorrhage | 18 (17.5%) |
| **Previous stroke History** | Yes | 4 (4%) |
| | No | 98 (96%) |
| **Comorbidities** | Hypertension | 31 (30.3%) |
| | Diabetes Mellitus | 39 (38.23%) |
| | Ischemic Heart Disease | 7 (6.8%) |

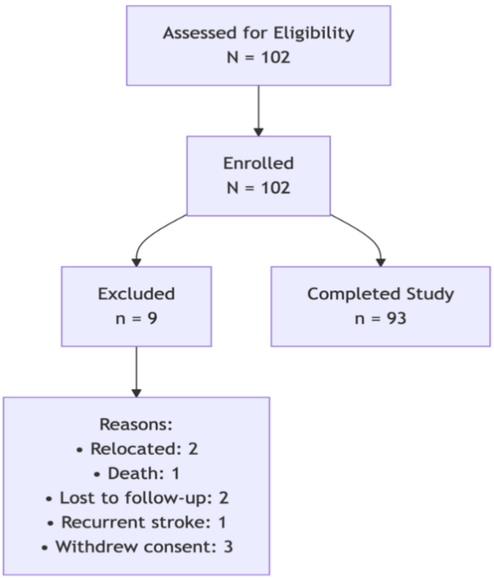


***Figure-1 Flowchart of patient enrollment and follow-up***

### *Clinical Characteristics in the Minor Stroke Group*

Patients scoring ≤4 on the NIHSS were stratified into this group. The average TIS score of 14.88±1.27 at week 1 post-stroke was 16.65±0.77 at week 6 and 19.53±0.53 at week 12, with a mean difference of 4.65 (p<0.01). Hip flexor strength at baseline was 23.66±4.91 to 25.44±5.27 on week 12, having a mean difference of 1.78 (p>0.05). Statistically significant findings were observed in the FAC at bassline vs at week 12 post-stroke (p<0.01). Similarly, the PASS showed a significant difference between week 1 and week 12 (p<0.01) in patients with minor stroke groups. The details are provided in Table-2.

**Table-2. Week-wise Clinical Characteristics Minor Stroke of Acute-Sub-acute Stroke Patients**

| Variables | Week 1 | Week 6 | Week 12 | MD | p-value |
|---|---|---|---|---|---|
| TIS | 14.88±1.27 | 16.65±0.77 | 19.53±0.53 | 4.6 | <0.01 |
| MI- Hip | 23.66±4.91 | 23.85±3.71 | 25.44±5.27 | 1.78 | >0.05 |
| FAC | 2.11±0.71 | 2.41±0.73 | 3.43±1.08 | 1.32 | <0.01 |
| PASS | 13.5±0.73 | 14.8±0.51 | 16.9±1.15 | 3.40 | <0.01 |

*Note: Values are given as Mean ± S.D. Corresponding p-value was calculated utilizing the Repeated Measure One-Way ANOVA. Abbreviations: TIS, Trunk Impairment Scale; MI, Motricity Index; FAC, Functional Ambulatory Category; PASS, Postural Assessment Scale for Stroke.*

### *Clinical Characteristics in the Moderate Stroke Group*

Patients scoring <20 on the NIHSS were stratified into this group. The average TIS score of 12.63±1.27 at week 1 post-stroke was 14.65±0.77 at week 6 and 17.43±0.53 at week 12, with a mean difference of 4.80 (p<0.01). Hip flexor strength at baseline was 21.62±5.19 to 24±5.25 on week 12, having a mean difference of 2.15 (p>0.05). Statistically significant findings were observed in the FAC at bassline vs at week 12 post-stroke (p <0.01). Similarly, the PASS showed significant differences between week 1 to week 12, (p<0.01) in patients with moderate stroke group. The details are provided in Table-3.

**Table-3. Week-wise Clinical Characteristics Moderate Stroke of Acute-Sub Acute Stroke Patients**

| Variables | Week 1 | Week 6 | Week 12 | MD | p-value |
|---|---|---|---|---|---|
| TIS | 12.63 ±1.27 | 14.65 ±0.77 | 17.43 ±0.53 | 4.80 | <0.01 |
| MI-HIP | 21.62±5.19 | 21.85±3.71 | 24.00 ±5.25 | 2.15 | >0.05 |
| FAC | 1.23 ±0.71 | 1.68±0.73 | 1.93±0.61 | 0.70 | <0.05 |
| PASS | 10.50 ±0.73 | 12.6 0.51 | 13.7±1.15 | 3.20 | <0.01 |

*Note: Values are given as Mean ± S.D. Corresponding P value was calculated utilizing the Repeated Measure One-Way ANOVA. Abbreviations: TIS, Trunk Impairment Scale; MI, Motricity Index; FAC, Functional Ambulatory Category; PASS, Postural Assessment Scale for Stroke.*

We conducted a week-wise correlation analysis at baseline, week 6, and week 12 post-stroke. At week 1 post-stroke, FAC had a moderate correlation with TIS (r=0.57, p=<0.05) and PASS (r=0.59, p=<0.05). However, no significant correlation was observed between Hip extensor strength and FAC (r=0.23, p=>0.05). The week 1 correlation matrix is explained in Table-4.

**Table-4 Correlation Matrix Week 1 Post-stroke**

| | TIS | FAS | HES | PASS |
|---|---|---|---|---|
| TIS | 1.00 | 0.57* | 0.20 | 0.43 |
| FAC | | 1.00 | 0.23 | 0.59* |
| MI-HIP | | | 1.00 | 0.32 |
| PASS | | | | 1.00 |

*Note: values are given for "r value". Corresponding P value was calculated utilizing the Pearson Correlation coefficient. Abbreviations: TIS, Trunk Impairment Scale; MI, Motricity Index; FAC, Functional Ambulatory Category; PASS, Postural Assessment Scale for Stroke.*
**Indicates P=<0.05, **indicates P=<0.01*

Similarly, at week 6 post-stroke, FAC had a moderate correlation with TIS (r=0.60, p=<0.05) and PASS (r=0.68, p=<0.05). However, no significant correlation was found between Hip extensor strength and FAC (r=0.41, p=>0.05). The week 6 correlation matrix is explained in Table-5.

**Table-5 Correlation Matrix week-6 post stroke**

| | TIS | FAC | HES | PASS |
|---|---|---|---|---|
| TIS | 1.00 | 0.60* | 0.32 | 0.49 |
| FAC | | 1.00 | 0.41 | 0.68* |
| HES | | | 1.00 | 0.39 |
| PASS | | | | 1.00 |

*Note: Values are given for "r value". Corresponding P value was calculated utilizing the Pearson Correlation coefficient. Abbreviations: TIS, Trunk Impairment Scale; MI, Motricity Index; FAC, Functional Ambulatory Category; PASS, Postural Assessment Scale for Stroke.*
**Indicates P=<0.05, **indicates P=<0.01*

Moreover, at week 12 post-stroke, FAC had a strong positive correlation with TIS (r=0.72, p=<0.05) and PASS (r=0.77, p=<0.05). A moderate correlation was observed between Hip extensor strength and FAC (r=0.55, p=>0.05). The week 12 correlation matrix is explained in Table-6.

**Table-6 Correlation Matrix week-12 post stroke**

| | TIS | FAC | HES | PASS |
|---|---|---|---|---|
| **TIS** | 1.00 | 0.72** | 0.50* | 0.55* |
| **FAC** | | 1.00 | 0.55* | 0.77** |
| **HES** | | | 1.00 | 0.46 |
| **PASS** | | | | 1.00 |

*Note: values are given for "r value". Corresponding P value was calculated utilizing the Pearson Correlation coefficient. Abbreviations: TIS, Trunk Impairment Scale; MI, Motricity Index; FAC, Functional Ambulatory Category; PASS, Postural Assessment Scale for Stroke.*Indicates P=<0.05, **indicates P=<0.01.*

## DISCUSSION

The findings of our longitudinal study provide valuable insights into the recovery trajectories of stroke patients, particularly focusing on the relationship between trunk and postural control, hip muscle strength, and functional ambulation. We found noteworthy differences in outcomes between the minor and moderate stroke groups. For patients with minor strokes, the significant increase in TIS scores over time illustrates the potential for recovery in trunk control, indicating that even patients with initial deficits can achieve substantial gains with appropriate intervention. Similarly, the significant changes observed in the FAC and the PASS highlight the importance of trunk stability in regaining ambulation skills. This aligns with earlier research indicating that a Trunk control test (TCT) score of 41 or higher at the onset of a stroke strongly predicts improved independent ambulation by 12 weeks post-stroke[12,24]. Studies have consistently shown that better trunk control is linked to greater mobility outcomes in stroke survivors[25-26].

The improvement patterns for the moderate stroke group mirror those of the minor stroke cohort, with significant enhancements in TIS scores, FAC, and PASS from baseline to week 12. This consistency across groups suggests that rehabilitation efforts focusing on trunk control may yield beneficial outcomes regardless of stroke severity. However, it is crucial to note that while hip flexor strength improved, it did not reach statistical significance, indicating a potential area for further investigation. A previous study by Smith et al. utilized the TCT to assess trunk performance.[12] However, recent research has demonstrated that the TIS is a more effective assessment tool, as the TCT is prone to a ceiling effect—where a substantial number of participants achieve the highest possible score—thereby limiting its ability to evaluate trunk function and progression accurately[16,27]. This insight highlights the importance of using the proper assessment tools to gauge progress and accurately tailor rehabilitation efforts for better outcomes.

Our correlation analysis findings shed light on the evolving relationship between trunk performance, hip muscle strength, and functional ambulation. Notably, the moderate to strong correlations observed at week 12 suggest that as patients progress in their recovery, trunk control and balance become increasingly critical to achieving independent ambulation. This finding emphasizes the need for clinicians to prioritize interventions that enhance trunk stability and control, particularly in the later stages of recovery when patients are transitioning to more independent mobility. Notably, the lack of significant correlation between hip flexor strength and FAC at various time points suggests that hip muscle strength alone may not be the sole determinant of walking ability post-stroke[28-29]. Instead, trunk control and postural stability may play a more pivotal role. This insight challenges us to rethink traditional rehabilitation protocols that may overly emphasize lower limb strength without adequately addressing trunk function[30].

The strengths of this study lie in its longitudinal design, the use of validated assessment tools, and a comprehensive analysis of correlation differences at various stages of stroke recovery, contributing to a deeper understanding of rehabilitation progress. However, the study's small sample size limits the generalizability of the findings. Secondly, we focused on specific assessment tools for trunk performance and postural stability, while other important biomechanical parameters, such as spatiotemporal gait characteristics, were not included due to feasibility constraints. Future research could incorporate these parameters and explore interventional strategies with a larger sample size to enhance the study's impact and applicability.

## CONCLUSION

Our study emphasizes that improved postural stability and trunk control at the onset of a stroke are strong predictors of independent ambulation at 12 weeks post-stroke. By prioritizing trunk control and postural stability, we can better support healthcare providers in helping their patients regain the ability to walk. This focus can have a profound impact on the recovery journey of stroke survivors. Future research should continue to explore these relationships and develop innovative rehabilitation approaches that leverage our study's findings, ultimately enhancing the quality of life for stroke survivors.

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### Author Contributions

**Salman Farooqi** contributed to the conceptualization, study design, manuscript drafting, and overall project oversight. **Saima Rehman** was responsible for data collection and interpretation, conducted the formal analysis, and ensured validation of findings. **Ifrah Masood** developed the methodology, performed statistical analysis, provided supervision, and approved the final manuscript. **Rabia Masood** conducted the literature review, assisted in manuscript editing, and contributed to the critical revision of the content.

### Ethical Approval

This study received approval from the Institutional Ethical Review Committee (Ref No: DIR/IPM&R-EC/202210-72) of Khyber Medical University, Peshawar, Pakistan.

### Grant Support and Funding Disclosure

None.

### Conflict of Interests

None.

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