***Original Research Article***

# The Impact of Upper Limb Functioning on Gait Patterns in Individuals with Post-Stroke Hemiplegia

**Abstract**

Hemiplegia resulting from stroke leads to distinct spatiotemporal gait pattern and upper limb dysfunction. This study aimed to determine the connection between upper limb functionality and selected gait parameters in post-stroke hemiplegic patients. The study involved 80 outpatients (45 males and 35 females) with post-stroke hemiplegia, averaging 60.78 years in age, selected through convenient sampling. The study employed the shortened Disabilities of the Arm, Shoulder, and Hand questionnaire (QuickDASH) to assess the affected upper limb functionality. Simultaneously, participants underwent video recording while performing the 4-meter walk test (4mWT). Comfortable and maximum speeds, paretic and affected side stride length, stride time, steps taken to cover the 4m and cadence, were meticulously calculated from the recorded videos using Kinovea software (version 0.8.15). Pearson Correlation analysis was conducted to uncover potential associations between these gait parameters and the QuickDASH score, with a significance level of $p < 0.05$.

The findings revealed significant correlations between upper limb functionality and various gait parameters. Reduced upper limb functionality correlated with decreased comfortable speed ($p < 0.05$), maximum speed ($p < 0.05$), and cadence ($p < 0.05$) during the 4mWT. In contrast, impaired upper limb function linked to prolonged time to complete the 4m distance ($p < 0.05$), increased steps taken by both affected ($p < 0.05$) and unaffected ($p < 0.05$) sides, and extended stride time on both sides ($p < 0.05$). However, no substantial correlation emerged between upper limb functionality and stride length on either side ($p > 0.05$).

In conclusion, this study emphasizes the interplay between upper limb functionality and specific gait parameters in post-stroke hemiplegic patients. The correlation between upper limb dysfunction and altered gait patterns underscores the necessity for integrated rehabilitation strategies targeting both upper limb and gait training. These findings enhance understanding of the intricate relationship between upper limb impairment and gait alterations, underscoring tailored interventions' importance for optimizing functional recovery in post-stroke patients.
**Keywords:** *Gait, QuickDASH, Stroke, Upper limb functionality, 4m walk test*



## Introduction

Stroke is a complex clinical syndrome resulting from presumed vascular origins, marked by the sudden onset of both local and global disruptions in cerebral functions, persisting for over 24 hours or leading to fatality (1). It stands as a significant contributor to adult disability and ranks as the fifth leading cause of death in Sri Lanka (2). The clinical presentation of stroke is heavily influenced by the size and location of the cerebral lesion (1,3). Hemiplegia, a common outcome of stroke, affects 80% of survivors and results in motor impairments involving the face, arm, and leg (4). This condition places substantial economic and psychological burdens on both affected individuals and their families (5). With the advancement of healthcare in Sri Lanka, survival rates for stroke victims have improved, leading to a significant number of survivors dealing with post-stroke disabilities necessitating rehabilitation (6). Notably, nearly 50% of post-stroke patients struggle with ambulation, 12% require assistance, while 37% eventually regain independent walking abilities (7). Local studies reveal that severe impairment affects around 35-40% of stroke survivors, with 10-15% confined to bed within a year (6). The loss of ambulation autonomy poses a significant barrier to the independence of stroke survivors. Moreover, 69% of post-stroke individuals experience compromised upper limb functionality (8, 9). To enhance the autonomy of affected patients, it's imperative to understand strategies that amplify the efficacy of existing treatments.

Existing research highlights the interconnected relationship between upper limb motor deficits and performance in movement tests. This suggests that enhancing upper limb functionality could potentially contribute to improved ambulation capacity (10). Additionally, there is a correlation between increased walking speed and enhanced coordination between the affected upper limb and the unaffected lower limb (11), underscoring the importance of addressing the affected upper limb to enhance gait coordination. Speed, as a pivotal factor, fosters inter-limb coordination and augments gait performance. Notably, significant improvements can be observed within the initial 3-6 months post-stroke in both upper limb (12,13) and lower limb (14) functions, as well as daily activity execution (15,16). These findings highlight the significance of initiating rehabilitation during the early stages of recovery to facilitate substantial enhancements in both upper and lower limb capacities.

In this study, meticulous calculations of spatiotemporal parameters were conducted to provide insights into the gait patterns of post-stroke patients. Spatial parameters encompass metrics like step length and stride length, while temporal parameters encompass time-related factors such as cycle duration and cadence. Various walking tests are available to assess spatiotemporal gait parameters. However, within the context of post-stroke hemiplegic patients, the intricate interplay between upper limb functionality and gait parameters has not been extensively explored.

## Methodology

**Subjects:** A total of 80 stroke patients, comprising 45 males and 35 females, were selected from the Neurology Physiotherapy Clinic at the National Hospital of Sri Lanka (NHSL), employing a convenient sampling method. The recruitment process adhered to specific eligibility criteria.

The defined inclusion criteria were as follows:

1. Individuals must have experienced their initial stroke event leading to unilateral hemiplegia.
2. Participants' age must exceed 50 years.
3. The stroke incident should have transpired at least 3 months prior to recruitment.
4. Participants should be capable of walking a distance of 20 feet unassisted.

On the contrary, the exclusion criteria encompassed the following conditions:

1. Absence of significant perceptual or communication disturbances.
2. No concurrent peripheral or central nervous system dysfunctions.
3. No active inflammatory or pathologic alterations in the lower limb joints within the preceding 6-month period.
4. Patients with severe weight-bearing pain, rated higher than 5 out of 10 on the visual analogue pain scale.
5. Individuals encountering severe balance issues, demonstrated by an inability to perform a tandem walk for a distance of 1 meter without external support.

Eligible patients who expressed their willingness to participate in the study were provided with a comprehensive explanation regarding the study's objectives and procedures. They were also furnished with information sheets to enhance their understanding of the study's aspects.

Ethical approval for the study was obtained from the Ethics Review Committee of the Faculty of Medicine at the University of Colombo. The corresponding ethical clearance code was UCP-AL-15-329. This ethical approval ensured the study's compliance with established ethical guidelines, and it underscored the safeguarding of the rights and well-being of the enrolled participants.

**Instrumentation:** Upon obtaining informed consent from each participant, a 4-meter walk test was systematically conducted. This test comprised a designated 2-meter span both at the outset and conclusion of the walking path to facilitate acceleration and deceleration. Data acquisition was confined to the central 4-meter segment of the walkway. Participants were duly instructed to traverse a level and smooth 8-meter-long walkway. To mitigate potential confounding factors stemming from participants' unfamiliarity with the experimental protocols, three iterations of the walk test were administered.

For a comprehensive analysis of participants' gait dynamics, video recordings were meticulously captured during the walking trials. Employing Kinovea software (version 0.8.15), the acquired videos were subject to meticulous examination to derive selected temporal and spatial gait parameters. The outcomes of this analysis were depicted in Figures 1A and 1B.

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To assess the extent of disability encompassing the arm, shoulder, and hand regions, the QuickDASH questionnaire was methodically employed. To accommodate participants' linguistic preferences, the questionnaire was available in multiple translations including English, Sinhala, and Tamil.

A meticulously structured interviewer-administered questionnaire, encompassing the QuickDASH questionnaire, was adeptly utilized to comprehensively assess the functional capacity of the impaired upper limb. Within the QuickDASH questionnaire framework, a numeric score of 0 connoted negligible disability within the afflicted upper limb. Conversely, ascending numerical values were indicative of increasing disability magnitude and concomitant reduction in upper limb functionality.

**Scoring Calculation:** To quantify the participants' responses, the arithmetic mean of their provided answers was computed.

The average value of all the answers was taken during calculation then reduce 1 from the average and multiply it by 25 to calculate the score of 100.

$$QuickDASH\ score = \left(\left[\frac{sum\ of\ n\ response}{n}\right] s - 1\right) \times 25$$

n=number of complete responses

**Data analysis:** One gait cycle of an available trial was selected for analysis. Temporal parameters; time of completion, comfortable speed, maximum speed, cadence, and stride time of the paretic side and unaffected side and spatial parameters; stride length, number of steps taken by the paretic side and unaffected side to cover 4m were calculated. Notably, step length, stride length, and velocity were normalized by dividing by body height. SPSS software (version 20) was used to analyze statistical data. Mean (±SD) of age and gait parameters were analyzed using descriptive statistics. Pearson correlation was used to identify the relationship between the QuickDASH score and the spatiotemporal parameters separately. The significance level was set at $p$=0.05.

**Analysis of Gait Cycle:** From among the available trial data, a singular gait cycle was chosen for meticulous analysis. The selected temporal parameters, including time of completion, comfortable speed, maximum speed, cadence, and stride time, were meticulously ascertained for both the paretic and unaffected sides. Similarly, spatial parameters, encompassing stride length and the count of steps undertaken by both the paretic and unaffected sides to traverse the 4-meter distance, were computed. Notably, step length, stride length, and velocity were normalized by dividing by body height.

**Statistical Analysis:** The SPSS software (version 20) was proficiently deployed. Descriptive statistics were harnessed to derive the mean (±SD) of selected factors such as age and gait parameters. In the pursuit of deriving relationships, Pearson correlation analysis was deftly applied. Specifically, this analysis aimed to analyze any associations between the QuickDASH score and the spatiotemporal parameters, each assessed independently.

**Significance Level:**

A criterion of statistical significance was unambiguously set at a threshold of p=0.05. This threshold was scrupulously adhered to when evaluating the statistical significance of observed outcomes and relationships.

*Figure 1A- Stride length of the unaffected side (Starting step which was used to measure stride length)*


*Figure 1B- Stride length of the unaffected side (End step which was used to measure stride length) (Font size of the values are much larger on the video than that appeared in the above image.)*



**Results**

The mean (±SD) of time of completion, comfortable speed, maximum speed, cadence, and stride time of the paretic side and unaffected side of the sample were 20.04s (±20.514), 0.36ms$^{-1}$ (± 0.23), 0.49ms$^{-1}$(±0.31), 69.55min$^{-1}$(± 23.58), 0.97s (± 0.31) and 0.88s (± 0.28) respectively. The mean (±SD) of the QuickDASH score of the sample was 39.34 (±20.83). As depicted in Figure 2; with the decrease in upper limb functionality, individual comfortable speed ($p$=0.0001), and maximum speed ($p$=0.00008), the cadence ($p$=0.001) of the gait decreases significantly ($p$<0.05). Although upper limb functionality has decreased, time taken to cover a 4m distance ($p$=0.003), steps taken by the paretic side ($p$= (0.007) and unaffected sides (p=0.04), stride time-paretic ($p$=0.046) and unaffected sides ($p$=0.036) were increased significantly ($p$<0.05). No statistically significant relationship was found between the stride length of the paretic side or the unaffected side with the upper limb functionality ($p$>0.05). Concerning the QuickDASH score and 4m walk test, moderate correlations were found for: time of completion, comfortable speed, maximum speed, and cadence.

Figure 2;

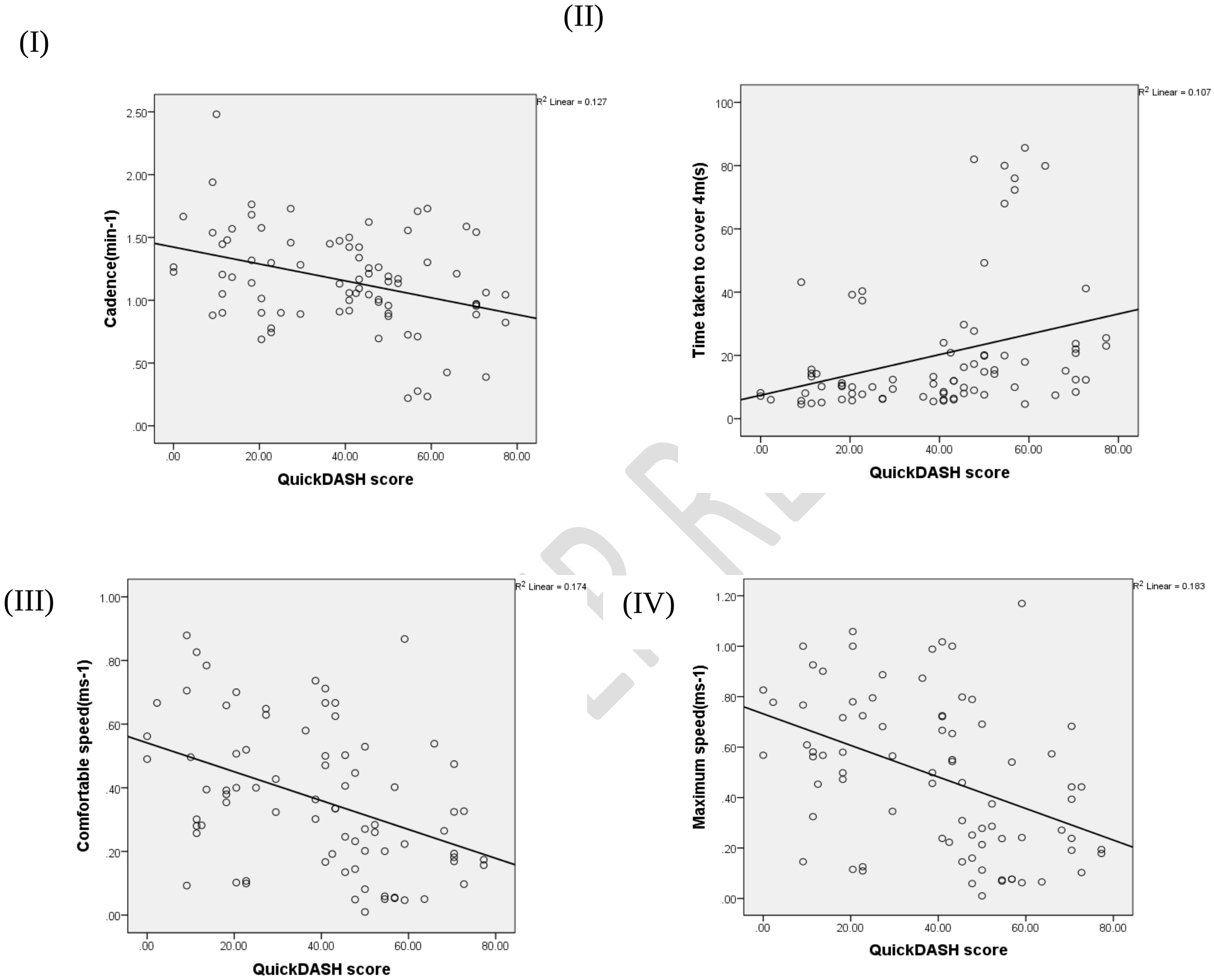


*Figure 2; Scatter plot diagram for correlation between QuickDASH score and (I) Cadence, (II) Time taken to cover 4m (III) Comfortable speed (IV) Maximum speed*

**Discussion**

Hemiplegia, characterized by paralysis on one side of the body, introduces a range of challenges affecting posture, weight-bearing, body weight transfer, and postural stability (17, 18). Eng and Chu (19) emphasize the notable discrepancy in gait abilities between affected (paretic) and unaffected (non-paretic) lower limbs in hemiplegic individuals. The paretic side, due to reduced weight-bearing capacity, exhibits slower gait velocity and diminished endurance. These gait recovery challenges are pivotal concerns in stroke patient rehabilitation (20), prompting various studies to introduce treatment approaches enhancing gait abilities (21).

The deficits caused by stroke encompass functional ambulation capacity, balance, walking velocity, cadence, stride length, temporal gait pattern, and muscular activity (22). This often leads to decreased paretic stance phase and increased paretic swing phase, demonstrating significant temporal gait alterations due to the limitations of the paretic limb.

Further complicating matters, upper extremity hemiparesis impacts daily activities such as dressing, bathing, and writing essential for functional independence. Therefore, rehabilitation programs play a crucial role in restoring functional autonomy (23). The severity of upper extremity hemiparesis significantly influences post-stroke disability and quality of life (8).

The study underscores that weakness in scapular stabilizers, caused by upper extremity hemiparesis, contributes to motor impairments, impairing body orientation adjustments and the maintenance of anatomical characteristics. This poses a challenge for independent daily living for many stroke survivors (24).

The study establishes a connection between spatiotemporal parameters like speed and cadence and upper limb functioning on the affected side of post-stroke hemiplegic patients. As speed and cadence increase, upper limb functioning improves, implying a relationship between upper limb rehabilitation and its impact on walking ability. This finding aligns with earlier literature and is supported by the results of R. Buraschia et al.'s study in 2018 (10).

Considering these findings, the study recommends an integrated rehabilitation approach combining upper limb and gait training for comprehensive benefits to stroke patients.

While a 10m walk test is ideal for gait analysis, limitations in space led to the selection of a 4m walk test with allocated space for acceleration and deceleration.

In summary, diminished upper limb functionality affects gait efficacy in post-stroke hemiplegic patients. Engaging patients in early upper limb exercises during rehabilitation is recommended to improve functionality, subsequently enhancing walking ability.

## Conclusions

With the decrease of upper limb functionality efficacy of gait was affected in a post-stroke hemiplegic patient. Hence, during the rehabilitation of post-stroke hemiplegic patients, it is recommended to engage the patient early in upper limb exercises to improve functionality, which will in turn help to improve walking.

## References


1. Alsop Helen, B. A. et al (2013) *Chapter 1*. 15th edn, *tidy's physiotherapy*. 15th edn. Edited by S. Porter. Elsevier.
2. Wijeratne, T. *et al.* (2011) 'Stroke care development in Sri Lanka: The urgent need for neurorehabilitation services', *Neurology Asia*, 16(2), pp. 149–151.
3. Raj, G. S. (2006) *Physiotherapy in Neuro-conditions*. 1st edn. New Delhi: Jaypee Brothers Medical Publishers.
4. Langhorne P, Coupar F, Pollock A. Motor recovery after stroke: a systematic review. Lancet Neurology 2009; 8:741- 54.
5. Venketasubramanian N, Yoon BW, Pandian J, Navarro JC. Stroke Epidemiology in South, East, and South-East Asia: A Review. J Stroke. 2017 Sep;19(3):286-294. doi: 10.5853/jos.2017.00234. Epub 2017 Sep 29. Erratum in: J Stroke. 2018 Jan;20(1):142. PMID: 29037005; PMCID: PMC5647629.
6. Gunaratne, P. (2012) 'Stroke in Sri Lanka: remedies for recovery', *Journal of the Ceylon College of Physicians*, 42(1–2), p. 3. doi: 10.4038/jccp.v42i1-2.4547.
7. Woolley, S. M. (2001) 'Characteristics of Gait in Hemiplegia', *Topics in Stroke Rehabilitation*, 7(4), pp. 1–18. doi: 10.1310/JB16-V04F-JAL5-H1UV.
8. Nakayama H. Jorgensen HS, Raashou HO, Olsen TS. Compensation in recovery of upper extremity function after stroke: the Copenhagen Stroke Study.ArchPhlvs Med Rehacbil 1994; 75: 852 57.

9. Luke, Carolyn; Dodd, Karen J; Brock, Kim (2004). *Outcomes of the Bobath concept on upper limb recovery following stroke. Clinical Rehabilitation, 18(8), 888–898.* doi:10.1191/0269215504cr793oa
10. Buraschi, R. *et al.* (2018) 'P 159 - Gait in stroke patients is influenced by upper limb functioning: A quantitative analysis correlating QuickDASH with Instrumented TUG and 10MWT', *Gait and Posture*. Elsevier, 65(xxxx), pp. 503–504. doi: 10.1016/j.gaitpost.2018.07.080.
11. Bovonsunthonchai, S. *et al.* (2012) 'Effect of speed on the upper and contralateral lower limb coordination during gait in individuals with stroke', *Kaohsiung Journal of Medical Sciences*. Elsevier Taiwan LLC, 28(12), pp. 667–672. doi: 10.1016/j.kjms.2012.04.036.
12. Nijland, R.H.M., Wegen, E.E.H., Van, & Wel, B.C.H., Der (2010). Presence of finger extension and shoulder abduction within 72 hours after stroke predicts functional recovery early prediction of functional outcome after stroke: The EPOS cohort study. Stroke, 45, 745-750.
13. Stinear, C.M., Barber, P.A., Petoe, M., Anwar, S. &Byblow, W.D. (2012). The PREP algorithm predicts potential for upper limb recovery after stroke. Brain, 135(8), 2527-2535.
14. Veerbeek, J.M., Van Wegen, E.E.H., Harmeling-Van der Wel, B.C. &Kwakkel, G. (2011). Is accurate prediction of gait in nonam- bulatory stroke patients possible within 72 hours poststroke? The EPOS study. Neurorehab Neural Re, 25(3), 268-274
15. Kwakkel, G., Kollen, B. &Twisk, J. (2006). Impact of time on improvement of outcome after stroke. Stroke, 37, 2348-2353
16. Prabhakaran, S., Zarahn, E., Riley, C., Speizer, A., Chong, J.Y., Lazar, R.M. & Krakauer, J.W. (2008). Inter-individual variability in the capacity for motor recovery after ischemic stroke.Neurorehab Neural Re, 22(1), 64-71
17. Horstmann, S, Koziol, JA, Martinez-Torres, F, Nagel, S, Gardner, H, and Wagner, S (2009). Sonographic monitoring of mass effect in stroke patients treated with hypothermia. Correlation with intracranial pressure and matrix metalloproteinase 2 and 9 expression. J Neurol Sci. *276*, 75-8.
18. Park, JH, Hwangbo, G, and Kim, JS (2014). The effect of treadmill-based incremental leg weight loading training on the balance of stroke patients. J Phys Ther Sci. *26*, 235-7.
19. Eng, JJ, and Chu, KS (2002). Reliability and comparison of weight-bearing ability during standing tasks for individuals with chronic stroke. Arch Phys Med Rehabil. *83*, 1138-44.Eng, JJ, and Chu, KS (2002). Reliability and comparison of weight-bearing

ability during standing tasks for individuals with chronic stroke. Arch Phys Med Rehabil. 83, 1138-44.

20. Jette, AM (2006). Toward a common language for function, disability, and health. Phys Ther. *86*, 726-34.
21. Stephenson, JL, Lamontagne, A, and De Serres, SJ (2009). The coordination of upper and lower limb movements during gait in healthy and stroke individuals. Gait Posture. *29*, 11-6.
22. Patterson, SL, Rodgers, MM, Macko, RF, and Forrester, LW (2008). Effect of treadmill exercise training on spatial and temporal gait parameters in subjects with chronic stroke: a preliminary report. J Rehabil Res Dev. *45*, 221-8.
23. Trombly, CA, and Wu, CY (1999). Effect of rehabilitation tasks on organization of movement after stroke. Am J Occup Ther. *53*, 333-44.
24. Hardwick, DD, and Lang, CE (2011). Scapular and humeral movement patterns of people with stroke during range-of-motion exercises. J Neurol Phys Ther. *35*, 18-25.