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


## ABSTRACT

Hemiplegia resulting from a stroke leads to a distinct gait pattern and dysfunction in the upper limb. The objective of this study was to determine a correlation between the functionality of the upper limb and selected spatiotemporal parameters of gait in patients with hemiplegia following a stroke. The study comprised a sample of 80 outpatients (45 males and 35 females) with post-stroke hemiplegia, with an average age of 60.78 years, selected using a convenient sampling method. To assess the functionality of the affected upper limb, the study employed the QuickDASH questionnaire, which is a shortened version of the Disabilities of the Arm, Shoulder, and Hand questionnaire. Concurrently, the participants were recorded on video while performing the 4-meter walk test (4mWT). The recorded videos were meticulously analyzed using Kinovea software (version 0.8.15) to calculate gait parameters such as comfortable and maximum speeds, stride length and time on the paretic and affected side, number of steps taken to cover the 4m, and cadence. Pearson Correlation analysis was conducted to explore 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 selected 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 correlation between upper limb functionality and specific gait parameters in post-stroke hemiplegic patients. The correlation between upper limb functionality and selected spatiotemporal parameters of gait underscores the necessity for integrated rehabilitation strategies targeting both upper limb and gait training. These findings contribute to a deeper comprehension of the connection between upper limb disability and gait parameters , emphasizing the significance of personalized treatments in order to maximize the restoration of functionality in individuals who have suffered a stroke.



*Keywords: QuickDASH score, Post-Stroke hemiplegia, 4m walk test, Stroke, Gait parameter*

## 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.

**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 1 and 2.
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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.

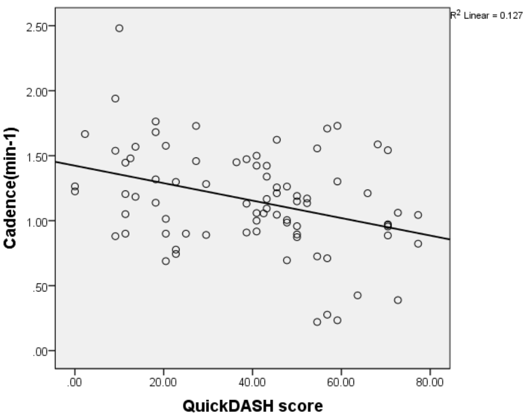
**Significance Level:** A criterion of statistical significance was unambiguously set at a threshold of p=0.05. This threshold was scrupulously adhered to when evaluating the statistical significance of observed outcomes and relationships.

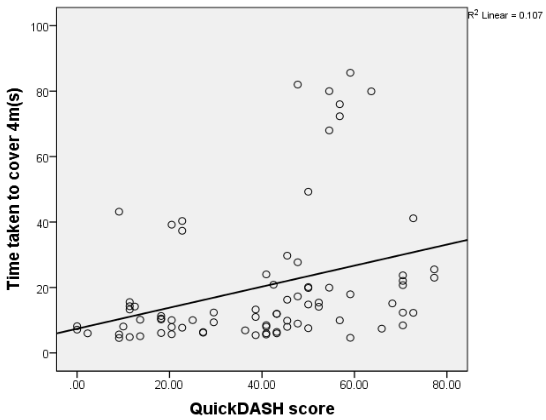
***Figure 1- Stride length of the unaffected side*** *(Starting step which was used to measure stride length)*


***Figure 2- 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 AND DISCUSSION

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 3; 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.



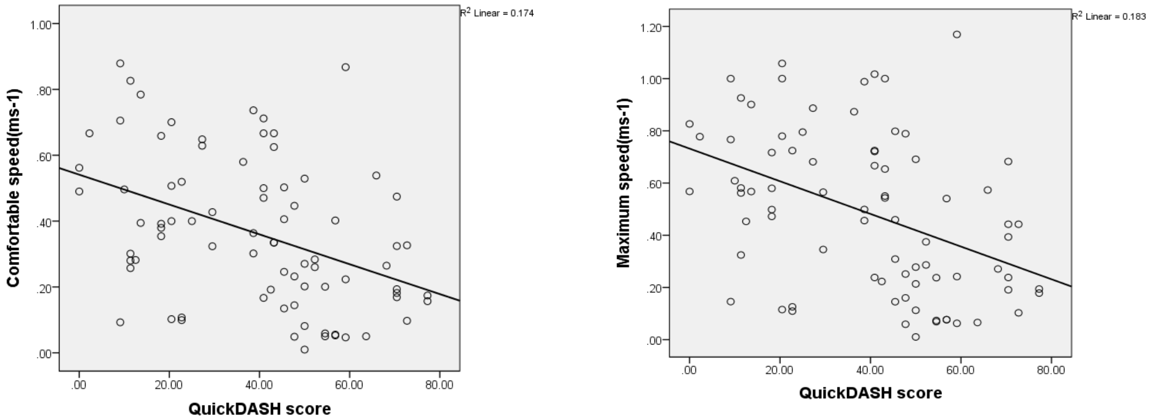



**Figure 3; Scatter plot diagram for correlation between QuickDASH score (I) Cadence, (II) Time taken to cover 4m, (III) Comfortable speed and (IV) Maximum speed**

The primary aim of this study was to assess the influence of upper limb functioning on the spatiotemporal parameters of gait in post-stroke hemiplegic patients. The findings revealed that specific spatiotemporal parameters demonstrated a moderate impact from upper limb functioning, while others did not display significant correlations.

Significantly, the study established moderate correlations between key spatiotemporal parameters, including speed, cadence, and the time required to cover a 4-meter distance, and the functioning of the affected side upper limb in post-stroke hemiplegic patients. The results indicated that as speed and cadence increased and the time taken to cover 4 meters decreased, upper limb functioning improved. This suggests a direct relationship between upper limb rehabilitation and its impact on walking ability, which aligns with prior research (10). However, it's important to note that weak correlations were observed for stride time, and no statistically significant relationships were identified for stride length on either the paretic or unaffected side. This discrepancy in findings for stride length contradicts previous literature (10), highlighting the need for further investigations in this area.

Earlier studies have highlighted the potential benefits of upper extremity exercises in enhancing lower limb muscle activity in both healthy adults and individuals with neuropathy (17). Recent research has also shown that voluntary arm swings during gait stimulate corticospinal tract activity and reflex reactions, subsequently enhancing lower limb muscle activities (18). Additionally, studies have demonstrated the impact of arm movement on walking speed, stride length, and pelvic and thoracic rotations in stroke patients (19). The coordination between the affected shoulder and contralateral hip movements has been linked to gait speed (11). In light of these findings, this study recommends an integrated rehabilitation approach that combines upper limb and gait training to maximize the benefits for stroke patients.

The study acknowledges that the 4-meter walk test, rather than the more commonly used 10-meter walk test, was employed due to space limitations in the clinical setting (20). To ensure the accuracy of the calculations, 2 meters were allocated at the start and end of the test for acceleration and deceleration purposes, with the central 4-meter segment dedicated to data collection. The use of parallel bars minimized the risk of falling, and the investigator walked closely behind the subjects for the safety and avoided alongside walking to prevent any unintended influence on their walking speed.

Despite the valuable insights gained from this study, several limitations should be noted. First, the study's small sample size. Additionally, the use of the 4-meter walk test, while necessary due to space constraints, may limit the applicability of the results to a broader population.

In summary, the study highlights the significant impact of upper limb functionality on gait efficiency in post-stroke hemiplegic patients. Early engagement in upper limb exercises during rehabilitation is recommended to enhance functionality, ultimately improving walking ability.

## CONCLUSION

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.

### Consent

As per international standards or university standards, patient(s) written consent has been collected and preserved by the author(s).

### ETHICAL APPROVAL

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.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Alsop Helen, B. A. et al . *Chapter 1*. 15th edn, *tidy's physiotherapy*. 15th edn. Edited by S. Porter. Elsevier. 2013
2. Wijeratne T. Neurorehabilitation in Sri Lanka: an emerging sub-specialty for neurology trainees. Int J Stroke. 2012 Feb;7(2):163-4. doi: 10.1111/j.1747-4949.2011.00625.x. Epub 2011 Oct 4. PMID: 21967513.
3. Raj, G. S. *Physiotherapy in Neuro-conditions*. 1st edn. New Delhi: Jaypee Brothers Medical Publishers. 2006
4. Li S. Spasticity, Motor Recovery, and Neural Plasticity after Stroke. Front Neurol. 2017 Apr 3;8:120. doi: 10.3389/fneur.2017.00120. PMID: 28421032; PMCID: PMC5377239.
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. ‘Stroke in Sri Lanka: remedies for recovery’, *Journal of the Ceylon College of Physicians*. 2009; 42(1–2), p. 3. doi: 10.4038/jccp.v42i1-2.4547.
7. Wang Y, Mukaino M, Ohtsuka K, Otaka Y, Tanikawa H, Matsuda F, Tsuchiyama K, Yamada J, Saitoh E. Gait characteristics of post-stroke hemiparetic patients with different walking speeds. Int J Rehabil Res. 2020 Mar;43(1):69-75. doi: 10.1097/MRR.0000000000000391. PMID: 31855899; PMCID: PMC7028468.
8. Roby-Brami A, Jarrassé N, Parry R. Impairment and Compensation in Dexterous Upper-Limb Function After Stroke. From the Direct Consequences of Pyramidal Tract Lesions to Behavioral Involvement of Both Upper-Limbs in Daily Activities. Front Hum Neurosci. 2021 Jun 21;15:662006. doi: 10.3389/fnhum.2021.662006. PMID: 34234659; PMCID: PMC8255798.
9. Luke, Carolyn; Dodd, Karen J; Brock, Kim. *Outcomes of the Bobath concept on upper limb recovery following stroke. Clinical Rehabilitation,* 2009;18(8), 888–898. doi:10.1191/0269215504cr793oa
10. Buraschi, R.,Pollet J2, Alghisi B *et al.* ‘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, 2018; 65(supplement 1), pp. 503–504. doi: 10.1016/j.gaitpost.2018.07.080.
11. Bovonsunthonchai S, Hiengkaew V, Vachalathiti R, Vongsirinavarat M, Tretriluxana J. Effect of speed on the upper and contralateral lower limb coordination during gait in individuals with stroke. Kaohsiung J Med Sci. 2012 Dec;28(12):667-72. doi: 10.1016/j.kjms.2012.04.036. Epub 2012 Jul 28. PMID: 23217359.
12. Nijland RH, van Wegen EE, Harmeling-van der Wel BC, Kwakkel G; EPOS Investigators. 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. 2010 Apr;41(4):745-50. doi: 10.1161/STROKEAHA.109.572065. Epub 2010 Feb 18. PMID: 20167916.
13. Stinear CM, Barber PA, Petoe M, Anwar S, Byblow WD. The PREP algorithm predicts potential for upper limb recovery after stroke. Brain. 2012 Aug;135(Pt 8):2527-35. doi: 10.1093/brain/aws146. Epub 2012 Jun 10. PMID: 22689909.
14. Veerbeek JM, Van Wegen EE, Harmeling-Van der Wel BC, Kwakkel G; EPOS Investigators. Is accurate prediction of gait in nonambulatory stroke patients possible within 72 hours poststroke? The EPOS study. Neurorehabil Neural Repair. 2011 Mar-Apr;25(3):268-74. doi: 10.1177/1545968310384271. Epub 2010 Dec 26. PMID: 21186329.
15. Ballester BR, Maier M, Duff A, Cameirão M, Bermúdez S, Duarte E, Cuxart A, Rodríguez S, San Segundo Mozo RM, Verschure PFMJ. A critical time window for recovery extends beyond one-year post-stroke. J Neurophysiol. 2019 Jul 1;122(1):350-357. doi: 10.1152/jn.00762.2018. Epub 2019 May 29. PMID: 31141442; PMCID: PMC6689791.
16. Ghose M, Das R, Barua AR, Deka P, Barman A, Borah NC, Chowdhury N, Barman A. A Five-Year Retrospective Cohort Study of Survivality and Functional Outcomes of Stroke Patients Following Hospital Admission. Ann Neurosci. 2022 Apr;29(2-3):144-150. doi:

10.1177/09727531221109106. Epub 2022 Jul 19. PMID: 36419511; PMCID: PMC9676343.

17. Panpan Yu, Wei Zhang, Yansheng Liu, Caihong Sheng, Kwok-Fai So, Libing Zhou, Hui Zhu. Chapter Eight - The effects and potential mechanisms of locomotor training on improvements of functional recovery after spinal cord injury. International Review of Neurobiology, 2019; 147: 199-217. doi: 10.1016/bs.irn.2019.08.003. (https://www.sciencedirect.com/science/article/pii/S0074774219300686)
18. Ogawa T., Sato T., Ogata T., Yamamoto S.I., Nakazawa K., Kawashima N. Rhythmic arm swing enhances patterned locomotor-like muscle activity in passively moved lower extremities. Physiol. Rep. 2015;3:e12317. doi: 10.14814/phy2.12317. [PMC free article]
19. Stephenson J.L., De Serres S.J., Lamontagne A. The effect of arm movements on the lower limb during gait after a stroke. Gait Posture. 2010;31:109–115. doi: 10.1016/j.gaitpost.2009.09.008.
20. Peters DM, Fritz SL, Krotish DE. Assessing the reliability and validity of a shorter walk test compared with the 10-Meter Walk Test for measurements of gait speed in healthy, older adults. J Geriatr Phys Ther. 2013 Jan-Mar;36(1):24-30. doi: 10.1519/JPT.0b013e318248e20d. PMID: 22415358.
21. Ng SS, Au KK, Chan EL, Chan DO, Keung GM, Lee JK, Kwong PW, Tam EW, Fong SS. Effect of acceleration and deceleration distance on the walking speed of people with chronic stroke. J Rehabil Med. 2016 Oct 5;48(8):666-670. doi: 10.2340/16501977-2124. PMID: 27534654.