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Mobility profile of chronic stroke classified as Functional Ambulation Category level 4: a cross-sectional study

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Abstract

Background: To profile gait, balance, and balance confidence in ambulatory adults with chronic stroke classified as Functional Ambulation Category (FAC) level 4.

Design: Cross-sectional study

Methods: In a single standardized session, force-platform balance measures (center of pressure sway velocity; limits of stability area), clinical scales (Berg Balance Scale; Timed Up and Go), overground 10-m walking speed, instrumented treadmill spatiotemporal metrics, and the Activities-specific Balance Confidence scale were obtained. Analyses were descriptive; continuous variables are presented as mean ± standard deviation (SD) and 95% confidence intervals (CIs), and categorical variables as n (%).

Results: Mean comfortable overground gait speed was 0.74 m/s, and clinical balance performance was high (Berg Balance Scale 47/56 on average), indicating generally good objective mobility. Instrumented treadmill data showed a hemiparetic gait pattern, with shorter paretic step length and reduced paretic single-limb support relative to the non-paretic side. In contrast, balance confidence was only moderate (mean Activities-specific Balance Confidence 66%), and most participants scored below 70%, suggesting that perceived steadiness lagged behind measured capacity in many individuals.

Conclusion: In independently ambulatory adults with chronic stroke at FAC level 4, objective gait and balance capacity were generally good, whereas balance confidence was modest, indicating a discordance between physical capacity and self-perceived stability. These descriptive profiles may help clinicians and researchers when planning interventions and future studies for this transitional subgroup of ambulatory stroke survivors, and should be interpreted in light of the single-center cross-sectional design and the absence of endurance and participation measures.

Key words: Balance, Confidence, Community ambulation, Gait, Stroke

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Ⅰ. Introduction

Stroke remains a leading cause of long-term disability worldwide, leaving many survivors with persistent motor impairments (Feigin et al., 2021). Because mobility underpins independence, gait restoration is a central focus of rehabilitation after stroke (Winstein et al., 2016). Community ambulation usually refers to independent walking outside the home in everyday public environments, such as neighbourhood streets or shops (Lord et al., 2004). By roughly six months post-stroke, many individuals walk independently on level surfaces (Smith et al., 2017). However, their walking speed often remains below thresholds that are considered necessary for full community ambulation (van de Port et al., 2008). Comfortable overground gait speed measured over a middle 10 m walkway segment is widely used to classify household, limited community, and community ambulators, and speeds of about 0.8 m/s or higher are typically interpreted as compatible with community-level walking (Bowden et al., 2008). Even among people who no longer need hands-on assistance, reduced balance confidence and fear of falling can limit outdoor walking and reduce participation in daily activities (Schmid et al., 2012).

Functional Ambulation Category (FAC) is a clinical measure used to classify ambulation ability after stroke based on the amount of physical support required from another person (Mehrholz et al., 2007). In this scale, FAC levels 2 and 3 typically describe individuals who still need continuous or intermittent manual assistance, whereas FAC level 5 indicates independent walking in all environments, including stairs and uneven surfaces (Mehrholz et al., 2007). FAC level 4 indicates that a person can ambulate independently on level surfaces but still requires supervision or occasional assistance for stairs, inclines, or uneven terrain (Yoo & Lim, 2022). Individuals at FAC level 4 therefore represent a transitional subgroup of ambulatory chronic stroke survivors who are beyond strictly household ambulation yet may not achieve fully independent community ambulation (van de Port et al., 2008). Clarifying the gait speed, balance performance, and balance confidence profile of this specific subgroup can help identify residual limitations and guide future studies that compare FAC level 4 with lower (FAC 2-3) and higher (FAC 5) ambulation levels. In this study, we interpreted outcomes within two domains: physical capacity in gait and balance, and self-perceived balance confidence. Physical capacity was characterised by overground 10-m gait speed, instrumented treadmill spatiotemporal parameters, and force-platform and clinical balance measures, with spatiotemporal parameters referring to step length, stride length, cadence, and single-limb support time that describe the temporal and spatial organisation of walking (Olney & Richards, 1996). Balance confidence, defined as a person's perceived ability to maintain stability during everyday tasks, was assessed with the Activities-specific Balance Confidence scale, which has established reliability and validity in people with stroke (Powell & Myers, 1995). Therefore, the purpose of this study was to comprehensively assess gait characteristics (speed and spatiotemporal parameters), balance (static, dynamic, and functional), and balance confidence in chronic stroke survivors with FAC level 4 ambulation. We hypothesised that, despite their independent level-surface walking ability, these individuals would exhibit gait speed limitations, residual balance impairments, and reduced balance confidence relative to their objective capacity.

II. Methods

1. Participants

This single-center, observational cross-sectional study enrolled inpatient adults with chronic stroke classified as FAC level 4 between January and October 2025. Participants were recruited consecutively from routine clinical services at a secondary-care hospital during the study period. Eligible individuals were aged 18 years or older with a clinical diagnosis of stroke at least 6 months prior, able to ambulate independently on level ground without physical assistance (FAC level 4) with or without a walking aid, able to stand quietly for at least 60 seconds with eyes open, and able to understand and follow simple test instructions (Cheng et al., 2021). Individuals were not included if they had additional neurological conditions that could affect balance or gait (e.g., Parkinson's disease, cerebellar ataxia, peripheral neuropathy), lower-limb orthopedic disease or pain limiting weight bearing or step length (e.g., an acute fracture or lower-limb surgery within 6 months), untreated vestibular disorders or severe uncorrected visual impairment, unstable cardiopulmonary disease that would preclude standardized walking tests, or any condition judged to compromise the safe completion of instrumented balance tasks or the 10-meter walk (Miyata et al., 2022). This study was approved by the Institutional Review Board of Bundang Jesaeng Hospital (IRB No. DMC 2023-03-002), and all participants provided written informed consent in accordance with the Declaration of Helsinki.

2. Sample Size Calculation

Sample size was determined a priori for the primary outcome of comfortable overground 10 m gait speed. A systematic review of comfortable gait speed responsiveness in adults with pathology, including stroke, reported minimal clinically important differences in the range of 0.10–0.20 m/s (Bohannon & Glenney, 2014). Recent gait studies in ambulatory individuals with chronic stroke have reported baseline standard deviations for comfortable gait speed of approximately 0.25-0.35 m/s (Avelino et al., 2019). On this basis, an absolute difference of 0.15 m/s, together with an assumed standard deviation of 0.30 m/s, was specified for planning, corresponding to a standardized effect size of 0.50 for a one-sample t test. Using this effect size, a two-sided alpha of 0.05, and 80% power, an a priori sample size calculation performed in G*Power 3.1 indicated that 34 participants would be required; accordingly, the planned sample size for this study was set at 40 participants.

3. Study Procedures

All assessments were completed in one standardized laboratory session (60–75 min). On arrival, eligibility and safety were confirmed (stroke ≥6 months, FAC level 4, ability to follow instructions), followed by seated orientation. After a 5-min rest, the examiner explained each task and, when applicable, provided one familiarization trial. A licensed physical therapist closely guarded all standing and walking tasks. The fixed sequence was seated administration of the Activities–specific Balance Confidence (ABC) scale, force-platform balance testing, Berg Balance Scale (BBS), Timed Up and Go (TUG), overground 10-Meter Walk Test (10MWT), and instrumented treadmill gait acquisition.

Center of pressure (COP) and limits of stability (LOS) assessments were obtained using a force platform (BT4, HUR Labs, Tampere, Finland). Participants stood barefoot in a shoulder-width stance with approximately 30° external foot rotation, arms at the sides, and eyes open fixating on a wall target. Trials involving a step or external support were discarded and immediately repeated. For COP, two 60-s quiet-standing trials were collected and averaged to compute mean COP velocity (cm/s). For LOS, after one practice trial, participants shifted the center of mass toward eight targets (anterior, posterior, left, right, and diagonals) without stepping and returned to center; two valid trials were averaged to obtain total LOS area (cm^2).

The BBS was administered once according to standardized instructions. The Timed Up and Go (TUG) was administered once following standardized procedures. From a seated position on a standard chair with armrests, participants stood at the go cue, walked 3 m at a comfortable pace, turned around a floor mark, returned, and sat. Timing ran from the go cue to back contact with the backrest. One practice trial was permitted if needed. Overground walking was tested on a 14-m straight walkway at self-selected speed, with timing over the middle 10 m after a 2–m acceleration and before a 2–m deceleration. Three trials were performed with 1–2 min of seated rest between trials, and the mean time was converted to gait speed (m/s) and later interpreted using established ambulation categories. Treadmill gait was acquired last on an instrumented system sampling at 120 Hz. Belt speed was set to each participant's mean overground speed from the 10MWT, calculated as 10 m divided by the mean of the three trial times (m/s), and this speed was kept constant during treadmill testing. After a 2-min accommodation at this speed, during which handrails were permitted, a 30-s capture without handrail support was obtained. Trials in which handrails were grasped or a clear misstep occurred were discarded and immediately repeated. Mean values were exported for belt speed (m/s), cadence (steps/min), paretic step length (cm), stride length (cm), and paretic single-limb support (% gait cycle). Across all tests, 1-3 minutes of seated rest were provided to minimize fatigue, and any protocol deviation prompted immediate repetition. Continuous outcomes followed prespecified averaging rules. force-platform measures were the mean of two successful trials, the 10MWT the mean of three trials, the ABC, BBS, and TUG single administrations, and treadmill variables 30–s means.

4. Outcome Measures

For interpretation, outcomes were grouped into two domains: physical capacity in gait and balance, and self-perceived balance confidence. Physical capacity was captured by force-platform balance indices, clinical balance tests, overground gait speed, and instrumented treadmill spatiotemporal gait parameters, whereas self-perceived balance confidence was captured by the Activities-specific Balance Confidence scale.

1) Balance outcomes

Balance outcomes comprised four domains. Static balance was quantified as COP mean velocity (cm/s) during 60-s quiet standing on a force platform, with lower values indicating better postural stability (Bruyneel et al., 2022); dynamic balance was assessed as the LOS area (cm^2) during volitional center of gravity shifts to eight targets without stepping, where larger areas reflect a wider controllable stability range (Lininger et al., 2018); functional balance was measured with the BBS (14 items, 0–56) administered by a trained therapist, with higher scores denoting better balance and strong measurement properties in stroke (Miyata et al., 2022); and balance confidence was captured with the ABC scale (16 items, 0–100%), which shows robust psychometric support in stroke populations (Seamon et al., 2019).

2) Gait outcomes

Gait outcomes comprised three components. Overground walking was assessed with the 10MWT, using the middle 10 m of a 14 m walkway at self-selected pace; mean time (s) was the primary metric, with cohort-level velocity derived secondarily (Cheng et al., 2021). For clinical context, gait speed was interpreted as $<$0.40 m/s (household), 0.40–0.80 m/s (limited community), and $\geq$0.80 m/s (community) (Bowden et al., 2008). Instrumented treadmill spatiotemporal metrics were obtained on a gait-analysis treadmill (FDM-T, Zebris Medical GmbH, Isny im Allgäu, Germany) sampling at 120 Hz, exporting 30-s means for belt speed (m/s), cadence (steps/min), paretic step length (cm), stride length (cm), and paretic single-limb support time (% gait cycle); temporal parameters show good to excellent repeatability, with acceptable to excellent reliability reported for Zebris systems (Encarnación-Martínez et al., 2021; Van Alsenoy et al., 2019).

5. Data analysis

All analyses were descriptive and used data from a single standardized assessment with no intervention. Continuous variables are reported as mean ± standard deviation (SD) with 95% confidence intervals (CI) for the mean using the student t distribution, and categorical variables as *n* (%). Missing data were handled by complete-case analysis with the number of cases reported. No hypothesis testing or multiplicity adjustments were planned; estimates were interpreted by magnitude and precision. Analyses were performed in IBM SPSS Statistics, version 25 (IBM Corp., Armonk, NY, USA).

Ⅲ Results

1. Participants

Forty ambulatory adults with chronic stroke at FAC level 4 completed the standardized session (*n*=40); 57.5% were male, mean age 57.18 ± 8.62 years, height 165.78 ± 7.13 cm, weight 65.27 ± 9.64 kg, and time since stroke 39.72 ± 9.18 months; Mini-Mental State Examination–Korean version (MMSE-K) 27.83 ± 1.87. Stroke type was infarction 55.0% and hemorrhage 45.0%; affected side right 55.0%, left 45.0%. See 〈Table 1〉 for full summaries.

Table 1. The general characteristics of the subjects (*N* = 40)

Variable	Mean ± SD
Height (cm)	165.78 ± 7.13
Weight (kg)	65.27 ± 9.64
Age (years)	57.18 ± 8.62
Korean Mini-Mental State Examination (score)	27.83 ± 1.87
Time since stroke (months)	39.72 ± 9.18
Gender	
Male	23 (57.5%)
Female	17 (42.5%)
Diagnosis	
Infarction	22 (55.0%)
Hemorrhage	18 (45.0%)
Affected side	
Left	18 (45.0%)
Right	22 (55.0%)

Note. Continuous variables are presented as mean ± SD; categorical variables as n (%).

2. Balance and balance confidence

In instrumented quiet standing, COP sway velocity was 2.19 ± 0.77 cm/s (95% CI, 1.94-2.43), and LOS area 100.62 ± 15.73 cm^2 (95% CI, 95.59-105.65). On clinical testing, BBS was 47.40 ± 3.76 (95% CI, 46.20-48.60) and TUG 13.57 ± 2.88 s (95% CI, 12.65-14.49). Balance confidence (ABC) averaged 66.36 ± 14.27% (95% CI, 61.80-70.92). Details are provided in 〈Table 2〉.

Table 2. Balance and gait outcomes (FAC level 4)

Variable	Mean ± SD	95% CI for mean
Balance		
Center of pressure sway velocity (cm/s)	2.19 ± 0.77	1.94 - 2.43
Limits of stability area (cm²)	100.62 ± 15.73	95.59 - 105.65
Berg Balance Scale (score)	47.40 ± 3.76	46.20 - 48.60
Timed Up and Go (seconds)	13.57 ± 2.88	12.65 - 14.49
Activities-specific Balance Confidence (%)	66.36 ± 14.27	61.80 - 70.92
Spatiotemporal Gait		
10-Meter Walk Test (seconds)	13.55 ± 2.49	12.76 - 14.35
Treadmill velocity (m/s)	0.76 ± 0.15	0.72 - 0.81
Cadence (steps/min)	91.71 ± 7.02	89.47 - 93.96
Paretic step length (cm)	48.19 ± 5.82	46.32 - 50.05
Stride length (cm)	97.10 ± 9.54	94.04 - 100.15
Paretic single-limb support (% gait cycle)	33.28 ± 4.31	31.90 - 34.66

Note. Values are mean ± SD with 95% CIs for the group mean (t-based, *df* = 39). Treadmill velocity' refers to the conveyor-belt speed of the instrumented treadmill.

3. Gait performance

Overground 10MWT time was 13.55 ± 2.49 s (95% CI, 12.76-14.35); the cohort-level mean speed was 0.74 m/s, within limited-community ambulation and approaching the 0.80 m/s community threshold. On the instrumented treadmill, belt speed averaged 0.76 ± 0.15 m/s (95% CI, 0.72-0.81), cadence 91.71 ± 7.02 steps/min (95% CI, 89.47-93.96), paretic step length 48.19 ± 5.82 cm (95% CI, 46.32-50.05), stride length 97.10 ± 9.54 cm (95% CI, 94.04-100.15), and paretic single-limb support 33.28 ± 4.31% of the gait cycle (95% CI, 31.90-34.66). See 〈Table 2〉.

Ⅳ. Discussion

This study profiled gait, balance, and balance confidence in independently ambulatory chronic stroke survivors (FAC level 4). Gait speed was a particularly informative mobility measure. Walking speed is strongly linked to functional status and health in older adults (Middleton et al., 2015; Veronese et al., 2018). In stroke, gait velocity often categorizes ambulation ability; for instance, speeds ≥0.8 m/s are typically required for community-level walking. In this cohort, mean comfortable overground speed was 0.74 m/s, approaching the commonly cited 0.80 m/s threshold for community ambulation. However, this was only about 60% of age-matched healthy speed (Murtagh et al., 2021), underscoring a persistent mobility deficit despite independent walking ability. Even among FAC 4 independent walkers, the cohort's average speed was lower than that typically observed in healthy peers. This finding highlights the need to improve walking speed in rehabilitation.

Consistent with hemiparetic gait patterns, participants had shorter strides, lower cadence, and marked asymmetry in step length and weight-bearing (Chen et al., 2005; Olney & Richards, 1996). The paretic limb's support phase was notably brief, reflecting impaired weight transfer to the affected side (Wang et al., 2020). These spatiotemporal abnormalities stem from stroke-related muscle weakness and motor control deficits that limit forward propulsion and stepping speed. Importantly, gait asymmetry was associated with increased energy cost and higher fall risk: stroke survivors with more pronounced step-length asymmetry expend more energy and are more prone to balance loss (Little et al., 2020). Thus, even in FAC4 ambulators, residual gait deficits (slowness and asymmetry) are prevalent and clinically relevant. Improving gait speed and symmetry remains a key goal, as faster, more symmetric walking is linked to better community mobility and quality of life after stroke (Fulk et al., 2017).

Balance capacity in this cohort was generally high. The mean Berg Balance Scale (BBS) score was 47/56, generally consistent with low objective fall risk at the group level. Most individuals scored above 45, and any ceiling effect if present appeared limited at the group level. The Timed Up and Go (TUG) time averaged in the low-to-mid teens, suggesting only mild slowing relative to typical values reported in older adults. TUG performance was consistent with overall balance and walking status; no correlation analyses were prespecified. Overall, the balance and mobility outcomes suggest only mild residual impairment: patients could stand and walk independently with reasonably good balance, yet remained somewhat slower and less stable during dynamic tasks than healthy individuals.

A notable discordance was observed between physical balance capacity and self-perceived balance confidence. Despite high BBS scores, balance confidence was moderate on average (mean ABC 66%), suggesting that perceived steadiness may lag behind objective capacity in some individuals. 65% of the cohort had ABC <70% (Abou et al., 2021), reflecting the high incidence of falls post-stroke (Simpson et al., 2011). Additionally, some individuals reported low confidence, indicating perceived risk even during routine tasks and a persistent sense of vulnerability. Such low self-efficacy is associated with poorer physical function and perceived health status after stroke, highlighting its clinical importance beyond objective balance performance (Salbach et al., 2006). Although we did not collect detailed data on fall history, mood, or environmental barriers in this cohort, balance self-efficacy has also been identified as an independent predictor of satisfaction with community reintegration in older adults with chronic stroke, suggesting that unmeasured psychological and contextual factors may contribute to the discordance observed here (Pang et al., 2007). Confidence and objective balance measures represent different constructs, and no correlation analyses were prespecified or performed in this study. Clinically, balance confidence should therefore be considered alongside rather than as a proxy for measured capacity. In the broader literature, individuals with a fall history often report lower balance confidence despite comparable clinical balance scores, consistent with reports linking balance self-efficacy to fall history (Tamis et al., 2024). Psychological factors like fear of falling can persist long after stroke and do not necessarily mirror actual balance capacity. Addressing this confidence gap is crucial, since fear itself can become a barrier to mobility.

These results emphasize the need to target both gait mechanics and psychological confidence. Rehabilitation for chronic stroke should purposefully address both movement mechanics and confidence. In this cohort, objective balance and gait performance were generally good, while balance confidence was only moderate highlighting the practical need to pair task-specific gait/balance practice with strategies that reduce fear of falling and support self-efficacy (e.g., graded exposure, progressive task difficulty, brief cognitive reframing within sessions). Notably, adding cognitive-behavioral components to task-oriented balance training has been reported to reduce fear of falling compared with training alone (Liu et al., 2019). Embedding such elements can help translate laboratory performance into safer, more willing participation in community walking.

Several limitations should be considered when interpreting these findings. First, this was a single-center observational cross-sectional study with a modest sample size, and all analyses were descriptive; the results therefore cannot support causal inference or strong prognostic conclusions and may not generalize beyond similar rehabilitation settings. In addition, we did not conduct correlation analyses between gait, balance, and balance confidence measures, which limits inferences about their interrelationships. Second, all data were collected within a single testing session using a fixed assessment order, and we did not evaluate test–retest reliability, so potential fatigue, learning effects, or order effects may have influenced performance, particularly during the later treadmill condition. Third, balance and gait were assessed under controlled laboratory conditions using a force platform and an instrumented treadmill in a quiet indoor environment, which may not fully reflect the demands of outdoor walking or busy community settings. Fourth, we did not maintain a screening log and thus could not characterize individuals who were ineligible or who declined participation, so some degree of self-selection bias is likely. Fifth, we did not collect measures of walking endurance or participation, such as the 6-minute walk test, Reintegration to Normal Living Index, or Community Integration Measure, and we were therefore unable to examine how gait capacity and balance confidence relate to broader aspects of community ambulation and participation. Within these limitations, the present results describe gait speed, spatiotemporal gait characteristics, standing balance, and balance confidence in a clearly defined FAC level 4 cohort and may assist clinicians and researchers when planning interventions and future trials for this transitional subgroup of ambulatory adults with chronic stroke.

V. Conclusion

Among ambulatory adults with chronic stroke (FAC level 4), mobility was generally good: overground gait speed averaged 0.74 m/s (close to the commonly cited 0.80 m/s community ambulation threshold), and both clinical and instrumented balance measures were high. Nevertheless, balance confidence remained only moderate, suggesting persistent fear of falling and perceived instability in everyday situations and indicating that gait speed is best viewed as a practical summary index of activity-level walking capacity rather than a direct measure of community participation. Rehabilitation should therefore combine gait and balance training with confidence-building strategies (e.g., graded exposure, progressively more challenging community-relevant tasks, brief cognitive–behavioural components), and longitudinal studies are needed to clarify how such combined approaches affect participation outcomes.

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