Original Article

Ambulation Outcomes After Robotic Gait Rehabilitation in a Regional Hospital: A 2-Year Retrospective Observational Study

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ABSTRACT

Objectives: To evaluate changes in the level of walking ability as measured by the Functional Ambulation Category (FAC) following 10 sessions of robotic gait rehabilitation

Study design: A retrospective observational study

Settings: Department of Rehabilitation Medicine, Maharat Nakhon Ratchasima Hospital, a public regional hospital in Thailand

Participants: A total of 162 patients diagnosed with stroke, traumatic brain injury (TBI), or incomplete spinal cord injury (SCI), who presented with ambulation impairments and who received robotic gait rehabilitation at a regional hospital between November 2022 and November 2024.

Methods: Medical records of patients with ambulation impairments who received robotic gait rehabilitation at a regional hospital between November 2022 and November 2024, completed 10 training sessions, and had available pre- and post-training ambulation outcome data were included in the analysis. General demographic characteristics, diagnoses and ambulation outcomes, including the FAC, were collected. FAC scores before training and after 10 training sessions were compared. Associations between clinical variables and improvements in FAC were analyzed.

Result: Among the 162 patients who received robotic gait rehabilitation at a regional hospital, 48 were excluded due to incomplete training or missing data, leaving 114 patients for analysis. More than half of the patients (54%) demonstrated improvement in FAC scores after 10 training sessions. No patients experienced a reduction in FAC following training. Factors significantly associated with FAC improvement included the interval from the neurological event and the patients' baseline FAC. Minor complications were reported, including muscle strain in eight patients and dizziness in one patient.

Conclusion: This retrospective analysis of 2 years of robotic gait rehabilitation services at a regional hospital demonstrated that more than half of the patients achieved at least a one level improvement in the FAC following training. Factors associated with FAC improvement included the interval from the neurological event and the patients' baseline FAC.

Keywords: Gait disorders, neurologic, robotics, rehabilitation, stroke, spinal cord injuries

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Introduction

Robotic gait rehabilitation has been shown to be an effective intervention for improving ambulation in patients with stroke, spinal cord injury (SCI), and other neurological disorders. However, a major limitation of this approach is its high cost.[1] Previous studies have demonstrated that the robot-assisted gait training (RAGT) facilitates gait recovery after stroke.[2-4] Among RAGT devices, end-effector and exoskeleton systems are the most commonly reported modalities.[5-9] Some evidence suggests that end-effector systems may be more effective in improving walking ability in patients with subacute stroke.[10,11] In addition to stroke, robotic gait devices have also been used to improve gait patterns in patients with SCI.[12,13] Nevertheless, achieving optimal outcomes requires well-trained physical therapists with a thorough understanding of the principles underlying robotic gait training devices.

At Maharat Nakhon Ratchasima Hospital, a tertiary regional referral center in northeastern Thailand, a commercial end-effector-type RAGT device (Figure 1) was introduced in November 2022. Patients with stroke, traumatic brain injury (TBI), or SCI who presented with gait impairment were prescribed robotic gait rehabilitation by physiatrists, typically at a weekly frequency. Training sessions were conducted by specialized, experienced physiotherapists, with session durations ranging from 10 to 40 minutes, depending on patient endurance. Functional Ambulation Category (FAC) scores were assessed at baseline by physiatrists and physiotherapists and were reassessed after completion of 10 robotic gait training sessions.

This robotic gait rehabilitation service represents a pioneering model in an Asian country. To date, no studies have evaluated changes in pre- and post-training FAC scores over

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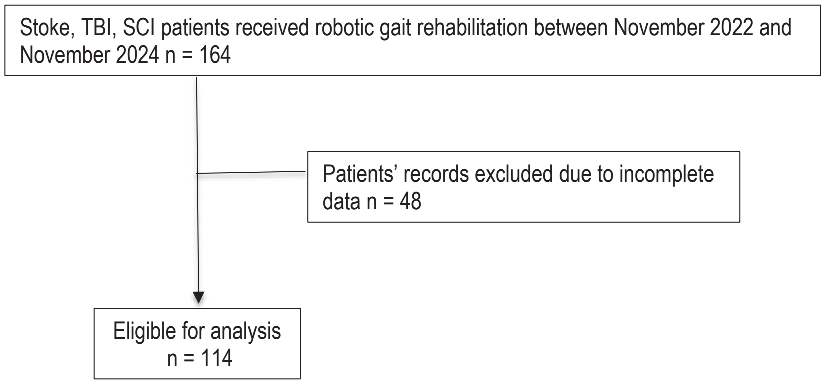

Figure 1. Participants

a 24-month period of robotic gait rehabilitation in real-world clinical practice in this setting. Therefore, the aim of this study was to evaluate ambulation outcomes following robotic gait rehabilitation, with a primary focus on changes in FAC scores before and after training.

Methods

This study retrospective observational study was conducted at the Department of Rehabilitation Medicine, Maharat Nakhon Ratchasima Hospital. Electronic medical records and robotic gait training data of all patients who received robotic gait rehabilitation between November 2022 and November 2024 were reviewed. The patients who completed 10 training sessions were included. Patients with incomplete ambulation outcome data were excluded.

General demographic data collected included age, sex, diagnosis (stroke, TBI , or spinal cord injury), interval from the neurological event, and health coverage. Ambulation outcomes were measured using the FAC before and after training, assessed by both physiatrists and physiotherapists, and recorded by the attending physiotherapists. The frequency of robotic gait rehabilitation and concurrent treatments—such as conventional physical therapy, traditional massage, and transcranial magnetic stimulation—was also documented. Complications related to robotic gait training were recorded. For patients who received more than one course of robotic gait rehabilitation, only the first course was included in the analysis.

Statistical analyses were performed using descriptive statistics for general demographic data such as age, gender, diagnosis, interval from the neurological events, health coverage, etc. Pre and post-training FAC are presented as descriptive statistics. The factors associated with FAC improvement were calculated by Fisher's exact test. Variables identified as potential confounders and those with a *p*-value < 0.10 in the univariable analysis were included in the multivariable logistic regression model. Age was categorized as < 60 years and ≥ 60 years prior to inclusion in the model. As this was a retrospective review of all eligible patients over a 24-month period, no formal sample size calculation was performed.

The present study was approved by the Ethics Committee of Maharat Nakhon Ratchasima Hospital (No.162/2024, approve on December 18, 2024) and was conducted in accordance with the STROBE guidelines.

Results

Over the 24-month study period, 162 patient records were initially identified. Of these, 48 cases were excluded due to incomplete ambulation outcome data, leaving 114 for comprehensive analysis. Patient demographic characteristics are summarized in Table 1. The patients' ages ranged from 17 to 87 years, with a predominance of male patients (72.8%). Stroke was the most common diagnosis. The interval from the neurological event and the robotic gait rehabilitation varied widely, ranging from 1 to 228 months. Hypertension was the most common comorbidity, affecting 36 patients (31.6%).

Table 2 shows the distribution of patients' pre- and post-training FAC. Initially, 20 patients (17.5%) had an FAC of 0, while 9 patients (7.9%) had the highest FAC score of 5. After

Table 1. Clinical characteristics of the patients (n = 114)

Characteristics	Number (%)
Mean age (years) (min-max)	54.48 (17-87)
Gender	
Male	83 (72.8)
Female	31 (27.2)
Diagnosis	
Stroke	80 (70.2)
TBI	23 (20.2)
SCI	11 (9.6)
Mean Interval after neurological events (months) (min-max)	13.95 (1-228)
Comorbidity	
Hypertension	36 (31.6)
Diabetes mellitus	18 (15.8)
Dyslipidemia	1 (0.9)
Health coverage	
UC	60 (52.6)
Government officer welfare	35 (30.7)
Social security	19 (16.7)

TBI, traumatic brain injury; SCI, spinal cord injury; UC, universal coverage

Table 2. Cross-tabulation of pre-training and post-training Functional Ambulation Categories (FAC)

Pre-training FAC (n)	Post-training FAC 0	Post-training FAC 1	Post-training FAC 2	Post-training FAC 3	Post-training FAC 4	Post-training FAC 5	Total
0	11	3	5	0	1	0	20 (17.5)
1	0	2	5	3	0	0	10 (8.8)
2	0	0	9	19	3	0	31 (27.2)
3	0	0	0	11	10	4	25 (21.1)
4	0	0	0	0	12	7	19 (16.7)
5	0	0	0	0	0	9	9 (7.9)
Total, n (%)	11 (9.6)	5 (4.4)	19 (16.7)	33 (28.9)	26 (22.8)	20 (17.5)	114 (100.0)

Table 3. Pre-treatment and post-treatment Functional Ambulation Classification (FAC) status and category transitions

Pre-treatment	Post- treatment: Dependent (FAC 0–3)	Post treatment: Independent (FAC 4–5)	Total, n (%)
Pre: Dependent (FAC 0–3)	67 (78.8%) (Remained dependent)	18 (21.2) (Gained independence)	85 (100%)
Pre: Independent (FAC 4–5)	0 (0.0%) (Lost independence)	29 (100.0%) (Remained independent)	29 (100%)
Total, n (%)	67 (58.8%)	47 (41.2%)	114

Table 4. Multivariate analysis of factors associated with Improved and unimproved Functional Ambulation Categories (FAC)

Factors	FAC improvement (n = 60)	FAC no improvement (n = 54)	*p*-value
Diagnosis			
Stroke	39 (65)	41 (75.93)	0.2
TBI	5 (8.33)	6 (11.11)	
SCI	16 (26.67)	7 (12.96)	
Interval from neurological events			
< 3 months	28 (46.67)	9 (16.67)	0.001
3-6 months	15 (25)	15 (27.78)	
> 6 months	17 (28.33)	30 (55.56)	
Training frequency/week			
< 3	15 (25)	19 (35.19)	0.306
> 3	45 (75)	35 (64.81)	
Received concomitant PT			
Yes	32 (53.33)	27 (50)	0.851
No	28 (46.67)	27 (50)	

TBI, traumatic brain injury; SCI, spinal cord injury; PT, physical therapy

training, the proportion of patients with an FAC of 0 decreased to 11 persons (9.6%), while those with an FAC of 5 increased to 20 (17.5%). This shift towards higher FAC indicates an improvement in functional ambulation levels. Of 114 patients, 54 (47.4%) showed no change in FAC, 44 (38.6%) improved by 1 level, 15 (13.2%) improved by 2 levels, and 1 (0.9%) improved by 4 levels. No patient experienced a reduction in FAC.

Pre- and post-training FAC levels stratified by gait independence are presented in Table 3. FAC scores of 0–3 were classified as dependent ambulation, whereas scores of 4–5 were classified as independent ambulation. Prior to training, 85 patients (74.6%) were classified as dependent ambulators, and 29 (25.4%) as independent ambulators. Following training, the proportion of dependent ambulators decreased to 67 patients (58.8%), and the proportion of independent ambulators increased to 47 patients (41.2%). Notably, 18 of the 85 patients (21.1%) who were initially gait-dependent achieved independent ambulation after training.

Univariable associations between factors and FAC improvement are shown in Table 4. The interval from the neurological event and pre-training FAC showed a significant association

Table 5. Multivariable logistic regression analyses of factors associated with improvement in Functional Ambulation Categories (FAC)

Factors	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)	*p*-value
Age < 60 years	1.08 (0.50, 2.35)	1.08 (.44, 2.58)	0.868
Interval from neurological events			
< 3 months	5.44 (2.15, 13.8)	4.46 (1.69, 11.68)	0.002
3-6 months	2.1 (0.77, 5.72)	2.01 (0.69, 5.87)	0.002
> 6 months	Ref.	Ref.	0.202
Pre-training FAC 0 -3	4.81 (1.85, 12.57)	3.69 (1.33, 10.26)	0.012
Training frequency			
> 3 times/week	1.63 (0.72, 3.65)	1.22 (0.49, 3.03)	0.667
Received concomitant PT	1.31 (0.62, 2.74)	1.07 (0.46, 2.48)	0.879

PT, physical therapy

with FAC improvement. Diagnosis, robot gait training frequency, and concomitant physical therapy did not show a statistically significantly association with FAC improvement. Multivariate analysis was performed and found that 2 variables were statistically significantly correlated with improvement in FAC were an interval from neurological event of less than 3 months and pre-training FAC 0-3, with adjusted odds ratios of 4.46 (95% CI: 1.70, 11.69) and 3.7 (95% CI: 1.33, 10.27), respectively. Multivariable logistic regression analysis was performed to identify factors associated with improvement in FAC (Table 5). After adjustment for potential confounders, patients with an onset of < 3 months had significantly higher odds of improvement compared with those with an onset of > 6 months (adjusted OR = 4.46, 95% CI: 1.70-11.87; p = 0.002). Patients with pre-training FAC scores of 0-3 also had significantly higher odds of improvement (adjusted OR = 3.70, 95% CI: 1.33-10.27; p = 0.012). However, age < 60 years, training frequency > 3 times per week, and receipt of concomitant physical therapy were not significantly associated with FAC improvement in the adjusted model.

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Concurrent treatments included conventional physical therapy, traditional massage, and transcranial magnetic stimulation. Of the 114 patients, 59 (51.8%) receiving conventional physical therapy, 1 (0.9%) received massage, and 1 (0.9%) received transcranial magnetic stimulation. There were reports of complications during robotics gait rehabilitation. The complications were 8 (7.0%) cases of muscle pain and 1 (0.9%) case of dizziness. These complications were mild and did not require additional medical treatment.

Discussion

Over 2 years of robotic gait rehabilitation, FAC improved in more than half (54.4%) of patients. Changes in FAC from pre-training to post-training show that most patients improved by 1 or 2 FAC levels. No patient experienced a decline in FAC either during or after the training program. These numbers represent real cases at a rural hospital who had received robotics-assisted gait rehabilitation as prescribed by physicians. The statistical numbers for selected cases and controlled environments may differ. Nevertheless, the outcomes of this study are consistent with previous studies.[1,5] Compared with conventional physical therapy, robotic gait rehabilitation offers the advantages of providing intensive, repetitive, and task-specific training.[2-4] Previous studies have also suggested that robotic gait rehabilitation may enhance motor recovery.[5,10,11]

The factors associated with FAC improvement were the interval from the neurological event and pre-training FAC. Patients with an interval of less than 3 months from the neurological event had greater FAC improvement than those in the other groups. This may be associated with robotic gait rehabilitation, which promotes motor recovery.[5,10,11] The other factor, pre-training FAC, was found to be one of the factors associated with FAC improvement in a previous study.[5] The present study also found that initial FAC was associated with FAC improvement. Patients with FAC of 0 and 1 were included in more studies than those with FAC of 2 to 5.5, because patients with lower FAC are more likely to improve their FAC after training. This is not the case in this study, which included all patients regardless of their initial FAC.

The complications found in this study were few (7.9%) and minor. These findings suggest that robotic gait rehabilitation is a relatively safe rehabilitation procedure. However, further observation is still required to ensure that there are no major or life-threatening complications in robotic gait training. One problem of robot gait rehabilitation is the loss of follow-up patients. Of the initial 162 patients, only 114 completed 10 sessions of robotic gait rehabilitation. The reasons for loss of follow-up varied among the patients, such as the long duration of the 10 sessions (at least 10 days), caregivers being unable to transport the patients to the treatment facility, etc. This problem had been partially solved by admitting the patients for inpatient robotic gait rehabilitation.

This study had some limitations. Firstly, this study was retrospective, so the authors could not provide data beyond what was recorded in medical records. Secondly, this study included heterogeneous neurological diagnoses (stroke, TBI, and SCI), each with different pathophysiological mechanisms and recovery trajectories. Therefore, the results may not be generalized to any specific diagnostic group. The results may not represent the specific group or disease. Thirdly, the absence of a control group prevented causal inference regarding the effectiveness of robotic gait rehabilitation. Improvement in FAC may have been influenced by spontaneous neurological recovery, concurrent rehabilitation therapies, or other uncontrolled confounders. Fourthly, variability in training intensity and session duration (ranging from 10 to 40 minutes) may have introduced additional heterogeneity in treatment exposure. Lastly, this study included all available data, even though some of that data would not have been included in other studies, which may have affected association analyses, such as the initial FAC[5], which would decrease overall FAC improvement due to the ceiling effect.

However, this study represents a real-life scenario in a rural hospital with limited opportunities for advanced therapies such as robotic gait training. This data may provide more insight into robotic gait rehabilitation in a certain region of an Asian country. Another advantage of this study is that it included more diseases than stroke, which were not included in previous studies. This study represents a large retrospective case series of more than 100 cases conducted over 24 months. Although it is not a prospective randomized controlled trial (RCT), the large sample size and longitudinal design enhance the reliability of the findings.

Conclusion

In conclusion, this retrospective analysis of 2 years of robotic gait rehabilitation services at a regional hospital demonstrated that more than half of the patients achieved at least a 1-level improvement in the FAC following training. Improvements in FAC were statistically significantly associated with the interval from the neurological event and the patients' baseline FAC.

Conflicts of interest declaration

The authors confirm that there is no conflict of interest related to the manuscript.

Generative AI declaration

The authors confirm that the following large language models (LLMs) or artificial intelligence (AI) tools were used in the preparation of this manuscript: ChatGPT for language editing and improving readability. All generated content was critically reviewed and edited by the authors.

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Data availability

The data that support the findings of this study are available from the corresponding author, Napatt Phusiripinyo, upon reasonable request.

Author contributions

Napatt Phusiripinyo: conceptualization, data curation, investigation, methodology, Visualization, writing - original draft

Rachawan Suksathien: conceptualization, methodology, resources, supervision, writing - review & editing

Paveenrath Charussuriyong: formal analysis, validation.

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