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Introduction

To address the limited availability of satisfaction information regarding gait training using a wearable overground exoskeleton for patients who have undergone spinal surgery, this study seeks to evaluate patients' satisfaction with robot-assisted gait training (RAGT).

Method

A retrospective registry was created for individuals referred to the Department of Rehabilitation Medicine between June and December 2023 after spinal surgery. Those who underwent early RAGT using ANGELLEGS M20 (Angel Robotics, Republic of Korea) were identified. A new gait training protocol for post-spinal surgery patients was adopted, featuring four assistive algorithms: stand-up mode, standing mode, walking mode, and stair-up and -down mode. The protocol was developed in collaboration with three physiatrists and two physical therapists experienced in musculoskeletal rehabilitation.

Participants had five sessions, each lasting 30 minutes, scheduled daily. RAGT could be conducted for an average of five weekdays, adjusting duration and level based on the patient's treatment condition. As functionality improved, the assistance level decreased, enabling more advanced movements.

The patient survey aimed to document self-reported adverse events and assess satisfaction for those undergoing RAGT. Patients receiving RAGT were encouraged to complete the survey. After the final session, physical therapists distributed and collected the questionnaires developed by us, with detailed information in Table 2.

Results

During the 6-month survey period, 32 patients underwent RAGT and participated in the survey, with their basic characteristics summarized in Table 1. All patients commenced RAGT, on average, 17.91 (9.76) days after surgery. Despite variations in the total number of sessions, the treatment was completed without any specific incidents, except for fatigue and muscle pain. The patients exhibited an improvement in FAC from 2.65 to 3.78 and in functional level from 2.19 to 3.44 when comparing their conditions at admission and discharge.

Regarding satisfaction results using a 5-point scale, the average score for satisfaction with the robotic device itself was 3.30, exceeding 3 points in all four aspects. Concerning RAGT, a satisfaction score of 3.72 was reported, and for future use, a score of 3.91 was recorded. Satisfaction with the effectiveness after treatment showed a total average score of 3.02, with sub-items scoring 3 or below, particularly in pain relief and discomfort during posture changes, suggesting a potential correlation between these two aspects.

Conclusion

This result indicates that RAGT can be implemented relatively early after spinal surgery without significant side effects, demonstrating the patients' satisfactory compliance. Through this, RAGT, employing a new treatment protocol, is expected to be a promising alternative as a new treatment method following spinal surgery.

Table 1. Protocol for robot-assisted gait training following post-spinal surgery utilized in this study.

Mode	Stage		
	1 st	2 nd	3 rd
A	Stand training for 30 seconds (stand mode)	Stand training for 30 seconds (stand mode)	Stand training for 30 seconds (stand mode)
		+ Squat training 20 times (squat mode)	+ Squat training over 20 times with slow sit down (squat mode)
B	Stand training for 1 minute (stand mode)	Stand training for 1 minute (stand mode)	Stand training for 1 minute (stand mode)
	+ Weight shift training with lifting hands alternately (stand mode)	+ Weight shift training with lifting feet alternately (stair mode)	+ Weight shift training with lifting one foot (stair mode)
C	Gait training (gait mode)	Gait training (gait mode)	Uneven level gait training or Stair up and down training
	Steps: 200 ~ 400 Cadence: < 50	Steps: 400 ~ 600 Cadence: < 65	

The robot is worn for a duration of 5 minutes. Each session, apart from the wearing time, involves A mode + (B or C mode), totaling 25 minutes. However, the selected modes and stages may vary depending on the patient's condition. In modes B and C, three assistive devices (harness with anterior walker, anterior walker only, crutch) may be utilized, chosen based on the patient's functional status.

Table 2. Survey questions for robot-assisted gait training (RAGT) designed for patients.

Questions for patients	
Related to robot	
1. Easy to wear	Did you find donning the exoskeleton easy?
2. Comfort to wear	Was the state of wearing the exoskeleton comfortable for you?
3. Noise	Do you consider the generated noise by the exoskeleton appropriate?
4. Weight	Is the weight of the exoskeleton suitable in your perception?
Related to RAGT	
5. Easy to adapt	Were you able to easily adapt to RAGT?
6. Improvement	Do you believe that your quality of life improved after undergoing RAGT?
7. Future use	Would you like to continue RAGT in the future?
8. Recommendation	Would you recommend RAGT to others?
Related to effectiveness	
9. Muscle power	Do you think that RAGT has been helpful in improving muscle strength and endurance?
10. Balance	Do you think that RAGT has been effective in improving balance?
11. Pain	Do you think that RAGT has been helpful in alleviating pain?
12. Change positions	Do you think that RAGT has been helpful in reducing discomfort when changing positions?
13. Fear of falling	Do you think that RAGT has been helpful in diminishing the fear of falling?
14. Walking ability	Do you think that RAGT has been beneficial in improving walking ability?

Responses to all questions could be scored on a scale ranging from 0 to 5. A score of 5 corresponds to "very satisfied," 4 to "satisfied," 3 to "neither dissatisfied nor satisfied," 2 to "dissatisfied," and 1 to "very dissatisfied."

Table 3. Basic characteristics of included patients (N = 32).

Characteristics	Patients
Age, years, mean (SD)	66.75 (13.11)
Sex, n (%)	
Men	11 (34.38%)
Women	21 (65.63%)
Surgical level, n (%)	
Cervical	6 (18.75%)
Thoracic	8 (25.00%)
Lumbar	18 (56.25%)
Time interval, days, mean (SD)	
From surgery to start of RAGT	17.91 (9.76)
FAC, mean (SD)	
Pre-training	2.65 (1.21)
Post-training	3.78 (0.71)
Functional level ^a	
Pre-training	2.19 (0.93)
Post-training	3.44 (1.08)

FAC, functional ambulatory category
^aWe categorized functional levels into five groups as follows: "wheelchair ambulation" is assigned 1 point, "walker-assisted gait" is assigned 2 points, "cane-assisted gait" is assigned 3 points, "independent indoor gait" is assigned 4 points, and "independent outdoor gait" is assigned 5 points.

Figure 1. Average satisfaction survey results of included patients measured using a 5-point scale.

