ARAŞTIRMA MAKALESİ / *RESEARCH ARTICLE*

Evaluation of Patient Satisfaction with the Use of Robotic Gait Devices in Stroke Patients

İnmeli Hastalarda Robotik Yürüme Cihazı Kullanımına Yönelik Memnuniyetin Değerlendirilmesi

Yakup Erden[1], Ahmet Burak Mavuş[1], Merve Tunçdemir[2]

[1]Clinic of Physical Medicine and Rehabilitation, Izzet Baysal Physical Treatment Training and Research Hospital, Bolu;
[2]Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Bitlis Eren University, Bitlis, Türkiye

ABSTRACT

Aim: *The aim of this study was to evaluate the satisfaction of stroke patients using assistive technology in robot-assisted gait training and to identify the factors associated with their satisfaction.*

Material and Methods: *A total of 60 patients with stroke, including 30 females and 30 males, were included in the study. Motor recovery stages of the upper and lower extremities were assessed using the Brunnstrom Motor Recovery Staging System, cognitive performance was evaluated with the Mini-Mental State Examination, and satisfaction with assistive technology use was measured using the Quebec User Evaluation of Satisfaction with Assistive Technology scale.*

Results: *Female patients had lower levels of satisfaction with assistive technology, cognitive performance, and certain sociodemographic and physical characteristics (age, height, weight) compared to males (p<0.05); however, their body mass index (BMI) values were similar. Both genders had comparable stroke-related characteristics. Satisfaction with assistive technology use showed a significant negative correlation with age (r=-0.393) and BMI (r=-0.302), and a significant positive correlation with height (r=0.542) and cognitive performance (r=0.658).*

Conclusion: *This study demonstrated that factors, especially gender and cognitive performance, should be taken into account in the use of assistive technologies in the field of stroke rehabilitation.*

Key words: *assistive technology; patient satisfaction; stroke rehabilitation*

ÖZET

Amaç: *Bu çalışmanın amacı robotik yardımlı yürüme eğitimi alan inmeli hastaların yardımcı teknoloji kullanımı memnuniyetlerini ve memnuniyetleri ile ilişkili faktörleri değerlendirmekti.*

Gereç ve Yöntem: *Çalışmaya 30'u kadın ve 30'u erkek toplam 60 inmeli hasta dâhil edildi. Alt ve üst ekstremite motor iyileşme evresi Brunnstrom motor iyileşme evreleme sistemi ile, bilişsel performans mini mental durum testi ile, yardımcı teknoloji kullanımı memnuniyeti ise Quebec yardımcı teknoloji kullanıcı memnuniyeti ölçeği ile değerlendirildi.*

Bulgular: *Kadın katılımcıların erkeklere kıyasla yardımcı teknoloji kullanımı memnuniyeti, bilişsel performans ve bazı sosyodemografik ve fiziksel özellikleri (yaş, boy, kilo) daha düşüktü (p<0,05); ancak vücut kitle indeksi (VKİ) değerleri benzerdi. İki cinsiyet de benzer inme karakteristiğine sahipti. Yardımcı teknoloji kullanımı memnuniyeti yaş (r=-0,393) ve BKİ (r=-0,302) ile negatif, boy (r=0,542) ve bilişsel performans (r=0,658) ile pozitif yönde anlamlı ilişki gösterdi.*

Sonuç: *Bu çalışma inme rehabilitasyonu alanında yardımcı teknolojilerin kullanımında cinsiyet ve bilişsel performans gibi faktörlerin göz önünde bulundurulması gerektiğini gösterdi.*

Anahtar kelimeler: *yardımcı teknoloji; hasta memnuniyeti; inme rehabilitasyonu*

Introduction

Although stroke is characterized by widespread sensorimotor impairments from head to toe [1,2], it is also considered one of the main causes of gait disturbances[3]. While motor recovery following stroke is mostly completed before the chronic phase, gait disturbances persist in some patients even during the chronic period[4]. Persistent gait disturbances, reported in approximately one-third of patients with chronic stroke[5], often lead to significant limitations in activities of daily living[6]. Furthermore, walking difficulties increase patients' susceptibility to falls and subsequently elevate the risk of fall-related fractures[7].

The significant limitations in activities of daily living caused by post-stroke gait disturbances[6], the limited

İletişim/Contact: *Yakup Erden, Izzet Baysal Physical Treatment and Rehabilitation Training and Research Hospital, Bolu, Türkiye •*
Tel: *0555 669 27 21 •* ***E-mail:*** *yakuperden@hotmail.com •* ***Geliş/Received:*** *09.07.2025 •* ***Kabul/Accepted:*** *16.07.2025*

ORCID: *Yakup Erden: 0000-0003-3742-9903 • Ahmet Burak Mavuş: 0009-0000-8147-159X • Merve Tunçdemir: 0000-0003-3453-6893*

effectiveness of conventional therapist-guided rehabilitation on gait restoration[7], and the recognition of gait recovery as one of the primary goals of stroke rehabilitation[8] have collectively laid the groundwork for the development of technological approaches such as robot-assisted gait training devices[9].

Robot-assisted gait training devices represent a post-stroke rehabilitation approach that provides patients with the opportunity for active, high-repetition, and high-dose functional gait practice—key components for gait restoration after stroke[10,11]. These devices also stimulate neural reorganization and brain adaptation[12]. Although various commercially available robot-assisted gait systems exist today[13], body weight-supported treadmill training systems are the most commonly used[14]. With the widespread adoption of robot-assisted gait devices, questions have also been raised regarding their actual effectiveness[15].

Although there is a substantial body of research on robot-assisted gait training in patients with stroke, most of these studies have primarily focused on evaluating the effects of robot-assisted gait devices on walking and balance using quantitative assessment tools[4,6,9,15,16]. While such approaches are valuable in demonstrating the measurable impact of robot-assisted gait training devices on patients' gait and balance performance – thus contributing to the development of evidence-based treatment strategies[4,6,9,15,16]– studies addressing patients' perceived functional improvements or subjective recovery experiences remain extremely limited[9]. Existing research has often been conducted with small sample sizes, and satisfaction with robot-assisted gait training devices has generally been evaluated as a secondary or supportive measure, rather than being examined as a primary outcome[17–21]. As is well known, motivation and active participation are critical components robot-assisted gait training[14], yet such advanced technologies may also provoke skepticism or fear among patients[22]. Furthermore, gaining insight into patients' personal experiences with robot-assisted gait training may contribute to the improvement and refinement of these devices[22].

In this context, our study aims to evaluate the satisfaction of stroke patients with the use of robot-assisted gait training devices and to identify the factors associated with their satisfaction levels.

Materials and Methods

Population and Sample

This cross-sectional and analytical observational study was conducted at Izzet Baysal Physical Treatment and Rehabilitation Training and Research Hospital. Patients were verbally informed before the study and provided written informed consent. Patients with stroke aged 18 years and older in the subacute or chronic phase who underwent three sessions of robot-assisted gait training during one week were included, while those with cognitive dysfunction or any additional neurological or neurodegenerative diseases were excluded (Fig. 1).

Due to the lack of similar studies with comparable characteristics, a post hoc power analysis was performed using G*Power 3.1.9.5 software, based on the correlation coefficient between the Mini-Mental State Examination Test (MMSE) scores and the questionnaire scores (r=0.68), and the study power was found to be 99%. The study protocol received approval from the local ethics and research committee and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

Data Collection Tools

To assess patients' satisfaction with robot-assisted gait training devices, patients participated in three sessions over one week, alongside a 40-minute conventional rehabilitation program aimed at improving gait and postural stability. The conventional program included

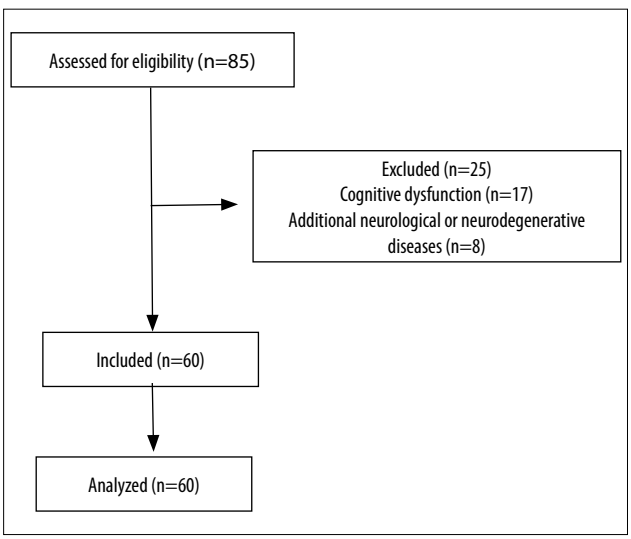

Figure 1. *Study flow chart.*

trunk positioning, manual-assisted overground training, and static and dynamic postural tasks[4].

Robot-assisted gait training was performed using the RoboGait® device (Bama Technology Middle East Technical University Teknokent, Ankara, Türkiye), with each session lasting 40 minutes. The device was adjusted to accommodate an appropriate lower extremity range of motion and to ensure symmetrical weight bearing, while compensatory movements were restricted. Training was conducted at a walking speed of 0.4 m/s with 50% body weight support[23]. During the session, patients engaged in a virtual reality game displayed on a 40-inch screen integrated into the device. In the game, patients were instructed to collect virtual coins while avoiding trees in a forest setting[24].

The motor recovery stages of the upper and lower extremities of the patients were evaluated using the Brunnstrom motor recovery staging system, which consists of six stages ranging from the flaccid stage to near-normal movement[25]. The Brunnstrom motor recovery stages demonstrated high inter-rater reliability, with coefficients ranging from 0.69 to 0.98. Strong agreement was noted for the upper extremity (r=0.89–0.98), hand (r=0.69–0.92), and lower extremity (r=0.80–0.95). In addition, overall consistency among raters was confirmed by Kendall's coefficient of concordance, which ranged between 0.89 and 0.95, all with statistically significant results[26]. The motor recovery stages of the upper and lower extremities were categorized for analysis as low recovery (Stages I–III) and high recovery (Stages IV–VI).

The cognitive performance of the patients was evaluated using the MMSE. The test consists of 11 items grouped under five main categories: orientation, registration, attention and calculation, recall, and language. The total score is 30 points, with each item scored on a one-point scale. The cutoff score for cognitive impairment is 23 points. Mini-mental state examination test has been shown to possess strong test-retest reliability (r=0.827–0.98) and consistent inter-rater reliability. Additionally, it exhibited satisfactory concurrent validity, with correlation coefficients ranging from 0.660 to 0.776[27].

Patients' satisfaction with assistive technology use was evaluated using the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST 2.0) scale. The scale consists of 12 items: eight related to the characteristics of the assistive device and four related to the assistive technology services. The eight-item section assesses user satisfaction with the device's features, while the four-item section evaluates how users experience the services provided as part of assistive technology. Each item on the scale is scored from 1 to 5 points, with 1 point reflecting no satisfaction at all and 5 points reflecting a high level of satisfaction[28]. For the evaluation, eight items from the scale addressing the following aspects were used: comfort, safety, ease of use, user adaptability, effectiveness, follow-up and training services, service delivery, and overall satisfaction.

Statistical Analysis

Continuous variables were presented as mean ± standard deviation or as median with minimum and maximum values, while categorical variables were summarized using frequencies and percentages. The assumption of normality was assessed using the Shapiro-Wilk test. Mann-Whitney U test, independent samples t-test, Fisher's exact test, and Chi-square test were used to compare sociodemographic, physical, stroke characteristics, and assistive technology satisfaction by gender, based on the variable type (continuous or categorical, nominal or ordinal) and whether the normality assumption was satisfied. Since the variables involved in the correlation analysis did not show a normal distribution, Spearman's rank correlation test was used. Statistical analysis was performed with the IBM Statistical Package for Social Sciences (SPSS) program version 27, and the significance level was adjusted as $p<0.05$.

Results

Among the patients, ischemic stroke was the most prominent type of stroke, and the middle cerebral artery was the most commonly affected. While more than half of the patients had a low level of motor recovery in the upper extremity, those with a low level of recovery in the lower extremity constituted more than three-quarters of the patients. All patients were in the chronic stage of the stroke (Table 1).

Female patients reported lower levels of satisfaction with assistive technology and cognitive performance, along with lower sociodemographic and physical characteristics such as age, height, and weight ($p<0.05$); however, their body mass index (BMI) values were similar to those of male patients. Both genders had similar stroke-related characteristics, including time

Table 1. *Sociodemographic, physical and stroke characteristics of the participants*

			Average	
Age (years)			58.53±12.58	
Height (cm)			164.41±11.02	
Body weight (kg)			78.50±13.74	
BMI (kg/cm^2)			29.00±4.20	
Brunnstrom stage of recovery			n	%
	I	Upper limb	-	-
		Lower limb	3	5
	II	Upper limb	10	17
		Lower limb	29	48
	III	Upper limb	27	45
		Lower limb	18	30
	IV	Upper limb	22	37
		Lower limb	10	17
	V	Upper limb	1	1
		Lower limb	-	-
Gender	Male		30	50
	Female		30	50
Time since stroke onset (month)			15.63±6.82	
Stroke type	Ischemic		49	82
	Hemorrhagic		11	18
Affected artery	MCA		53	88
	ACA		3	5
	PCA		4	7

BMI: body mass index; MCA: middle cerebral artery; ACA: anterior cerebral artery; PCA: posterior cerebral artery.

Table 2. *Comparison of sociodemographic, physical, stroke characteristics, and assistive technology satisfaction by gender*

	Male (n=30)		Female (n=30)			
	mean ± s. d.	Median (min-max)	mean ± s. d	Median (min-max)	z	p
QUEST score	39.76±0.50	40 (38–40)	37.53±1.59	37 (35–40)	5.566	<0.001*[a]
Age (years)	53.83±13.73	50 (30–79)	63.23±9.37	63 (46–79)	3.096	0.003*
Height (cm)	172.80±7.76	173 (158–186)	156.03±6.46	158 (144–169)	9.093	<0.001*
Body weight (kg)	84.16±13.73	84.5 (57–111)	72.83±11.35	73 (50–92)	3.483	<0.001*
BMI (kg/cm^2)	28.03±2.98	28.41 (20.68–32.83)	29.98±5.00	29.86 (22.03–42)	1.829	0.074
Time since stroke onset (month)	17.60±7.58	15.5 (7–32)	13.66±5.39	12.5 (6–26)	1.919	0.055[a]
Mini mental test score	28.30±1.29	28 (26–30)	26.63±1.40	26 (25–29)	4.040	<0.001*[a]
Brunnstrom stage of recovery	n	%	n	%		
Lower recovery stage for lower limb	24	80	26	87	0.480	0.488[c]
Higher recovery stage for lower limb	6	20	4	13		
Lower recovery stage for upper limb	16	53	21	70	1.763	0.184[c]
Higher recovery stage for upper limb	14	47	9	30		
Stroke type	n	%	n	%		
Ischemic	25	83	24	80	0.111	0.739[c]
Hemorrhagic	5	17	6	20		
Affected artery	n	%	n	%		
Middle cerebral artery	27	90	26	86	N. A.	1.000[b]
Anterior cerebral artery	1	3	2	7		
Posterior cerebral artery	2	7	2	7		

* p<0.05 statistical significance; independent sample t test; [a] Mann-Whitney U test; [b] Fisher's exact test; [c] Chi-square test; BMI: body mass index.

Table 3. *Correlation between outcome measures after talocrural joint manipulation and cavitation*

	Age		Height		Weight		BMI		MMSE score	
	r	p	r	p	r	p	r	p	r	p
QUEST score	-0.393**	0.002	0.542**	<0.001	0.072	0.584	-0.302*	0.019	0.628*	<0.001

* correlation is significant at the <0.05 level; ** correlation is significant at the <0.01; Spearman rank's correlation; BMI: body mass index; MMSE: mini-mental state examination.

Discussion

This study demonstrated that patients with stroke exhibit a very high level of satisfaction with robot-assisted gait training device technology, and that satisfaction levels are associated with gender, cognitive performance, and certain anthropometric variables.

Although previous studies have employed different robot-assisted gait training devices or protocols compared to our study, similar results have been reported[17–21]. Kim et al.[17] evaluated the usability of a robot-assisted gait training device in eight stroke patients, assessing four subdomains, including satisfaction, and found that patients reported very high levels of satisfaction. In a feasibility study conducted by Sung et al.[18], satisfaction with the use of a robot-assisted gait training device was assessed through a few questions among 13 predominantly chronic stroke patients (2 subacute, 11 chronic), and the results similarly indicated high levels of satisfaction. Another study by Fricke et al.[19], involving six patients with chronic stroke and four spinal cord injury patients, found that both groups were highly satisfied with the safety and comfort provided by the over-ground robot-assisted gait training device. In a study by Bortole et al.[20] involving three stroke patients, they expressed great excitement about using the over-ground robot-assisted gait training device. Similarly, Nilsson et al.[21] reported positive attitudes toward the over-ground robot-assisted gait training device among eight patients with stroke. While these studies demonstrated the safety and functional benefits of robot-assisted gait training with high levels of user satisfaction, the present study extends these findings by identifying how patient-specific factors –such as gender, cognitive performance, and anthropometric characteristics– are associated with satisfaction levels.

Considering that motivation and active participation are critical components in robot-assisted gait training[14], it can be suggested that these factors may have contributed to the high levels of satisfaction observed in our study.

Another factor influencing satisfaction with robot-assisted gait training devices is their standardized manufacturing design, which limits their use to individuals within certain anthropometric ranges (e.g., height: 150–170 cm; weight: ≤80 kg)[4,9,16,29]. This suggests that robot-assisted gait training devices may offer greater comfort for users whose anthropometric characteristics fall within these specifications. Consistent with this view, our study also found a correlation between certain anthropometric parameters, such as height and BMI, and satisfaction scores.

Another factor influencing satisfaction with robot-assisted gait training is the specific application protocol of the device[30]. In our study, a virtual reality component was integrated into the robot-assisted gait training sessions. Previous research has shown that the use of virtual reality in robot-assisted gait training enhances patients' active participation[30]. Given that active participation is largely influenced by patient motivation[31], it can be suggested that virtual reality contributes to improved motivation and engagement in robot-assisted gait training. In our study, the integration of virtual reality may have positively influenced patients' satisfaction with robot-assisted gait training.

Gait training with robot-assisted devices has been shown to require less energy expenditure and place less stress on the cardiorespiratory system[32]. These characteristic features of robot-assisted gait training devices may have contributed to the high levels of patient satisfaction observed in our study.

In our study, satisfaction levels with the robot-assisted gait training device differed according to gender. We believe this difference may be due to female patients being older than their male counterparts. This interpretation is supported by the well-established view that age is a significant factor contributing to poorer outcomes in patients with stroke[33]. Another study also reported that age is one of the key determinants of gains achieved through robot-assisted gait training[34]. Another study also reported that age is one of the factors influencing gait independence[35].

The lower satisfaction levels observed among female patients may also be partly explained by adverse events associated with the use of robot-assisted gait training devices. In body weight-supported robot-assisted gait training, the harness system may irritate areas such as the shoulders, armpits, and groin[36,37]. Although these adverse effects have been reported, the distribution of such events by gender was not specified[36,37]. Considering that musculoskeletal complaints are more prevalent in women than in men[38], that women tend to have lower pain thresholds and reduced tolerance to painful stimuli, and that female gonadal hormones are known to play a role in pain modulation[39], it is plausible that female patients were more sensitive to device-related discomfort. As a result, their satisfaction levels with robot-assisted gait training may have been negatively affected. To improve satisfaction, clinicians may consider individualized harness adjustments and proactive patient feedback, especially for those with higher sensitivity to discomfort. Device developers could address these issues by designing harness systems that are adjustable, size-inclusive, and gender-sensitive, using softer materials to reduce pressure-related complaints.

Lower satisfaction levels among female patients may also be partly attributed to their lower cognitive performance. Cognitive impairments can contribute to balance and gait difficulties[24] and are recognized as key factors in maintaining balance[40]. Although a harness supported patients during training, the influence of cognitive performance on balance control may still have affected their overall satisfaction with the use of the robot-assisted gait training device.

Another factor reported to influence the gains obtained from robot-assisted gait training is the Brunnstrom stage of motor recovery[34]. In our study, no significant difference was found between male and female patients in terms of their Brunnstrom motor recovery stages. This suggests that this factor did not play a role in the gender-based differences in satisfaction observed in our study and, at least indirectly, supports the findings of the previous study[34].

Limitations of the Study

Certain limitations of our study should be noted. The intervention duration in this study was relatively short, consisting of only three robot-assisted gait training sessions over one week, which may limit the understanding of long-term satisfaction and adherence. Future research should consider extended intervention durations and long-term follow-up assessments to evaluate these outcomes better. Additionally, the absence of a follow-up period restricts insights into whether the observed satisfaction levels were sustained over time or translated into functional improvements. The study relied solely on quantitative measures of satisfaction, lacking qualitative data that could have provided a deeper understanding of patients' subjective experiences. Potential response bias may have also influenced self-reported satisfaction, as patients might have responded favorably due to social desirability or expectations from clinicians. Future studies could incorporate qualitative interviews or open-ended survey items to capture these perspectives more comprehensively. Furthermore, the findings are device-specific, as only the RoboGait® system was utilized, limiting the generalizability of results to other robot-assisted gait training devices with different designs and features. Including multiple device types in future research would strengthen external validity. The cognitive assessment was limited and did not include a comprehensive neuropsychological evaluation, potentially overlooking subtle cognitive deficits that could affect satisfaction. Lastly, the absence of a control group receiving conventional gait training without robot assistance prevents a clear attribution of satisfaction effects solely to robot-assisted gait training.

Conclusion

Our study demonstrated that patients with stroke have a very high level of satisfaction with robot-assisted gait training devices assisting walking. That satisfaction is particularly associated with patients' cognitive performance and gender. In this context, considering individual factors such as gender and cognitive performance in the clinical setting of assistive technologies –specifically robot-assisted gait training devices– will contribute to the effective delivery of rehabilitation services in stroke rehabilitation.

References

1. Xu Y, Wang J, Wang S, Li J, Hou Y, Guo A. Neuromuscular conditions in post-stroke ankle-foot dysfunction reflected by surface electromyography. J Neuroeng Rehabil. 2024;21(1):137.
2. Dursun Ö, Dincer E, Durmuş B, Zengin ES. Effect of Dental Characteristics of Stroke Patients on the Masticatory System*. İstanbul Gelişim Üniversitesi Sağlık Bilimleri Dergisi. 2024(21):943–53.

3. Feigin VL, Lawes CM, Bennett DA, Barker-Collo SL, Parag V. Worldwide stroke incidence and early case fatality reported in 56 population-based studies: a systematic review. Lancet Neurol. 2009;8(4):355–69.
4. Yoshimoto T, Shimizu I, Hiroi Y, Kawaki M, Sato D, Nagasawa M. Feasibility and efficacy of high-speed gait training with a voluntary driven exoskeleton robot for gait and balance dysfunction in patients with chronic stroke: nonrandomized pilot study with concurrent control. Int J Rehabil Res. 2015;38(4):338–43.
5. Arienti C, Lazzarini SG, Pollock A, Negrini S. Rehabilitation interventions for improving balance following stroke: An overview of systematic reviews. PLoS One. 2019;14(7):e0219781.
6. Zhang LJ, Wen X, Peng Y, Hu W, Liao H, Liu ZC, Liu HY. Effectiveness of the A3 robot on lower extremity motor function in stroke patients: A prospective, randomized controlled trial. World J Clin Cases. 2024;12(24):5523–33.
7. Zhang F, Li K, Wu D, Chen P, Dou Z. Therapeutic effect of AiWalker on balance and walking ability in patients with stroke: A pilot study. Top Stroke Rehabil. 2021;28(3):236–40.
8. Dobkin BH. Clinical practice. Rehabilitation after stroke. N Engl J Med. 2005;352(16):1677–84.
9. Wall A, Borg J, Palmcrantz S. Self-perceived functioning and disability after randomized conventional and electromechanically-assisted gait training in subacute stroke: A 6 months follow-up. NeuroRehabilitation. 2019;45(4):501–11.
10. Prideaux N, Barr C, Drummond C, van den Berg M. Towards a Clinical Decision-Making Algorithm Guiding Locomotor Therapy Modality in Subacute Stroke: An Exploratory Study. J Stroke Cerebrovasc Dis. 2021;30(12):106112.
11. Yokota C, Tanaka K, Omae K, Kamada M, Nishikawa H, Koga M, et al. Effect of cyborg-type robot Hybrid Assistive Limb on patients with severe walking disability in acute stroke: A randomized controlled study. J Stroke Cerebrovasc Dis. 2023;32(4):107020.
12. Hsu TH, Tsai CL, Chi JY, Hsu CY, Lin YN. Effect of wearable exoskeleton on post-stroke gait: A systematic review and meta-analysis. Ann Phys Rehabil Med. 2023;66(1):101674.
13. Louie DR, Eng JJ. Powered robotic exoskeletons in post-stroke rehabilitation of gait: a scoping review. J Neuroeng Rehabil. 2016;13(1):53.
14. Tamburella F, Moreno JC, Herrera Valenzuela DS, Pisotta I, Iosa M, Cincotti F, et al. Influences of the biofeedback content on robotic post-stroke gait rehabilitation: electromyographic vs joint torque biofeedback. J Neuroeng Rehabil. 2019;16(1):95.
15. Hu MM, Wang S, Wu CQ, Li KP, Geng ZH, Xu GH, Dong L. Efficacy of robot-assisted gait training on lower extremity function in subacute stroke patients: a systematic review and meta-analysis. J Neuroeng Rehabil. 2024;21(1):165.
16. Yoshikawa K, Mizukami M, Kawamoto H, Sano A, Koseki K, Sano K, et al. Gait training with Hybrid Assistive Limb enhances the gait functions in subacute stroke patients: A pilot study. NeuroRehabilitation. 2017;40(1):87–97.
17. Kim KT, Choi Y, Cho JH, Lee S. Feasibility and Usability of a Robot-Assisted Complex Upper and Lower Limb Rehabilitation System in Patients with Stroke: A Pilot Study. Ann Rehabil Med. 2023;47(2):108–17.
18. Sung J, Choi S, Kim H, Lee G, Han C, Ji Y, et al. Feasibility of Rehabilitation Training With a Newly Developed, Portable, Gait Assistive Robot for Balance Function in Hemiplegic Patients. Ann Rehabil Med. 2017;41(2):178–87.
19. Fricke SS, Bayón C, der Kooij HV, EH FvA. Automatic versus manual tuning of robot-assisted gait training in people with neurological disorders. J Neuroeng Rehabil. 2020;17(1):9.
20. Bortole M, Venkatakrishnan A, Zhu F, Moreno JC, Francisco GE, Pons JL, Contreras-Vidal JL. The H2 robotic exoskeleton for gait rehabilitation after stroke: early findings from a clinical study. J Neuroeng Rehabil. 2015;12(1):54.
21. Nilsson A, Vreede KS, Häglund V, Kawamoto H, Sankai Y, Borg J. Gait training early after stroke with a new exoskeleton--the hybrid assistive limb: a study of safety and feasibility. J Neuroeng Rehabil. 2014;11:92.
22. Nedergård H, Sandlund M, Häger CK, Palmcrantz S. Users' experiences of intensive robotic-assisted gait training post-stroke - "a push forward or feeling pushed around?". Disabil Rehabil. 2023;45(23):3861–8.
23. Yakşi E, Bahadır ES, Yaşar MF, Alışık T, Kurul R, Demirel A. The effect of robot-assisted gait training frequency on walking, functional recovery, and quality of life in patients with stroke. Acta Neurol Belg. 2023;123(2):583–90.
24. Kayabinar B, Alemdaroğlu-Gürbüz İ, Yilmaz Ö. The effects of virtual reality augmented robot-assisted gait training on dual-task performance and functional measures in chronic stroke: a randomized controlled single-blind trial. Eur J Phys Rehabil Med. 2021;57(2):227–37.
25. Good DC, Bettermann K, Reichwein RK. Stroke rehabilitation. Continuum (Minneap Minn) . 2011;17(3 Neurorehabilitation):545–67.
26. Shah SK. Reliability of the Original Brunnstrom Recovery Scale Following Hemiplegia. Australian Occupational Therapy Journal. 1984;31(4):144–51.
27. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res. 1975;12(3):189–98.
28. Demers L, Weiss-Lambrou R, Ska B. The Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST 20): An overview of recent progress. Technol Disabil. 2002;14(3):101–105.
29. Winchester P, Querry R. Robotic orthoses for body weight-supported treadmill training. Phys Med Rehabil Clin N Am. 2006;17(1):159–72.
30. Bergmann J, Krewer C, Müller F, Koenig A, Riener R. Virtual Reality to control active participation in a subacute stroke patient during robot-assisted gait training. IEEE Int Conf Rehabil Robot. 2011;2011:5975407.

31. Pennycott A, Wyss D, Vallery H, Klamroth-Marganska V, Riener R. Towards more effective robotic gait training for stroke rehabilitation: a review. J Neuroeng Rehabil. 2012;9:65.
32. Lefeber N, Swinnen E, Kerckhofs E. The immediate effects of robot-assistance on energy consumption and cardiorespiratory load during walking compared to walking without robot-assistance: a systematic review. Disabil Rehabil Assist Technol. 2017;12(7):657–71.
33. Degami A, Taki S, Imura T, Iwamoto Y, Imada N, Tanaka R, et al. Early Initiation of Exoskeletal Robotic Gait Training Improves Functional Outcomes in the Patients with Stroke: A Retrospective Observational Study. Eur Neurol. 2023;86(2):121–7.
34. Taki S, Imura T, Mitsutake T, Iwamoto Y, Tanaka R, Imada N, et al. Identifying the characteristics of patients with stroke who have difficulty benefiting from gait training with the hybrid assistive limb: a retrospective cohort study. Front Neurorobot. 2024;18:1336812.
35. Carod-Artal FJ, Egido JA. Quality of life after stroke: the importance of a good recovery. Cerebrovasc Dis. 2009;27 Suppl 1:204–14.
36. Stoller O, de Bruin ED, Schindelholz M, Schuster-Amft C, de Bie RA, Hunt KJ. Efficacy of Feedback-Controlled Robotics-Assisted Treadmill Exercise to Improve Cardiovascular Fitness Early After Stroke: A Randomized Controlled Pilot Trial. J Neurol Phys Ther. 2015;39(3):156–65.
37. Chin LF, Lim WS, Kong KH. Evaluation of robotic-assisted locomotor training outcomes at a rehabilitation centre in Singapore. Singapore Med J. 2010;51(9):709–15.
38. Wijnhoven HA, de Vet HC, Picavet HS. Prevalence of musculoskeletal disorders is systematically higher in women than in men. Clin J Pain. 2006;22(8):717–24.
39. Traub RJ, Ji Y. Sex differences and hormonal modulation of deep tissue pain. Front Neuroendocrinol. 2013;34(4):350–66.
40. Capó-Lugo CE, Mullens CH, Brown DA. Maximum walking speeds obtained using treadmill and overground robot system in persons with post-stroke hemiplegia. J Neuroeng Rehabil. 2012;9:80.