Brain Neurorehabil. 2017 Sep;10(2):e9
https://doi.org/10.12786/bn.2017.10.e9
pISSN 1976-8753·eISSN 2383-9910

Brain & NeuroRehabilitation

Review

Check for updates

A Review of Robot-Assisted Gait Training in Stroke Patients

OPEN ACCESS

Ha Yeon Kim, Joshua Sung Hyun You

Received: Mar 17, 2017
Revised: May 10, 2017
Accepted: Jul 6, 2017

Correspondence to
Joshua Sung Hyun You
Movement Healing Laboratory, Department of Physical Therapy, Yonsei University Graduate School, 1 Yonsedae-gil, Wonju 26493, Korea.
Tel: +82-33-760-2476
Fax: +82-33-760-2496
E-mail: neurorehab@yonsei.ac.kr

Highlights

- End-effector type robot-assisted gait training systems were found to be more effective in locomotor recovery in stroke patients when they were applied in conjunction with conventional gait training rather than conventional gait training alone. However, this study does not confirm that the exoskeleton type robot-assisted gait training was more effective when it was applied in conjunction with the conventional gait training rather than the conventional gait training alone.
- The robot-assisted gait training paradigm offers intensive, repetitive, accurate kinematic feedback and symmetrical gait practice while reducing the workload for the therapist, reducing the cost of stroke rehabilitation.

Brain Neurorehabil. 2017 Sep;10(2):e9
https://doi.org/10.12786/bn.2017.10.e9
pISSN 1976-8753·eISSN 2383-9910

bnr
Brain & NeuroRehabilitation

Review

Check for updates

A Review of Robot-Assisted Gait Training in Stroke Patients

Ha Yeon Kim [1,2] Joshua Sung Hyun You [2]

[1]Translational Research Center for Rehabilitation Robots, National Rehabilitation Center, Seoul, Korea
[2]Movement Healing Laboratory, Department of Physical Therapy, Yonsei University Graduate School, Wonju, Korea

Received: Mar 17, 2017
Revised: May 10, 2017
Accepted: Jul 6, 2017

Correspondence to
Joshua Sung Hyun You
Movement Healing Laboratory, Department of Physical Therapy, Yonsei University Graduate School, 1 Yonsedae-gil, Wonju 26493, Korea.
Tel: +82-33-760-2476
Fax: +82-33-760-2496
E-mail: neurorehab@yonsei.ac.kr

ORCID iDs
Ha Yeon Kim
https://orcid.org/0000-0002-8314-3976
Joshua Sung Hyun You
https://orcid.org/0000-0001-9931-2466

Funding
This research received financial and administrative supports provided from "Brain Korea 21 Program for Leading Universities & Students (PLUS) Project" (grant No. 2016-51-0009) sponsored by the Korean Research Foundation for Department of Physical Therapy in Yonsei University Graduate School.

Conflict of Interest
The authors have no potential conflicts of interest to disclose.

ABSTRACT

While a variety of robot-assisted gait training systems have been widely applied for locomotor rehabilitation in stroke patients, the best supporting evidence for robot-assisted gait training systems remains unknown. The purpose of this study was to provide the best robot-assisted gait training and clinical evidence by comparing the effects of exoskeleton and end-effector type robot-assisted gait training in stroke rehabilitation. The present study underwent a review of the literature to determine the best clinical evidence of the most commonly utilized robot-assisted gait training paradigms (end-effector and exoskeleton types) in stroke gait rehabilitation. The review corroborates the compelling evidence that combined robot-assisted gait training was advantageous in stroke rehabilitation, as it offers additive special therapeutic effects that were not afforded by conventional therapy alone. Most importantly, the robot-assisted gait training paradigm provided more intensive, repetitive, accurate kinematic feedback and symmetrical gait practice, while reducing therapist labor, which is often not affordable in current stroke rehabilitation care. Both the robot-assisted gait training with either the end-effector type or exoskeleton type was beneficial for improving motor recovery, gait function, and balance in stroke patients when it was combined with the conventional physical therapy. The robot-assisted gait training should be used as an augmented gait intervention for stroke population.

Keywords: Robot-Assisted Gait Training; Stroke; End-Effector Type Robot; Exoskeleton Type Robot

INTRODUCTION

Hemiparetic gait impairment is a hallmark sequela in stroke victims and affects ambulation and quality of life [1]. Due to advanced medical technology and care, the mortality rate from stroke has significantly decreased. However, as many as 80% of stroke survivors suffer from locomotor dysfunction, which is characterized as asymmetrical step length, slow velocity, and altered biomechanical alignment [2,3].

Hemiparetic gait kinematics encompass excessive ankle plantar flexion during the swing phase and knee hyperextension and hip flexion during the stance phase, whereas kinetically decreased and asymmetrical ground reaction force is manifested during the push up phase. Recent stroke rehabilitation evidence suggests that a large number of repetitions (> 600) [4] and accurate sensorimotor feedback (e.g., kinematics and kinetics) are necessary to produce neuroplastic changes and associated locomotor functional recovery in stroke patients [5].

To restore hemiparetic gait, 2 innovative robot-assisted gait training paradigms utilizing the end-effector and exoskeleton robot types have recently been adopted to provide an ample number of repetitions with precise kinematics and kinetic sensorimotor feedback. In fact, the cumulative robotics studies demonstrated promising effects when robot-assisted gait training was employed using either end-effector or exoskeleton types in conjunction with conventional gait training. Conventional gait training often poses inherent issues, as it is labor intensive, costly, and does not provide accurate sensorimotor feedback.

Hence, the present study underwent an extensive review of the literature to determine the best clinical evidence of the most commonly utilized robot-assisted gait training paradigms (end-effector and exoskeleton types) in stroke gait rehabilitation.

End-effector devices work by applying mechanical forces to the distal segments of limbs. In end-effector devices, a subject's feet are placed on foot-plates, whose trajectories simulate the stance and swing phases during gait training [6]. End-effector type robots offer the advantage of easy setup, but suffer from limited control of the proximal joints of the limb, which could result in abnormal movement patterns. Examples of end-effector devices are the Gate Trainer GT1 (Reha-Stim, Berlin, Germany) and the G-EO-System (Reha Technology AG, Olten, Switzerland). In contrast, exoskeleton-type robotic devices have robot axes aligned with the anatomical axes of the wearer. These robots provide direct control over individual joints, which can minimize abnormal posture or movement. Construction of exoskeleton-type devices is more complex and more expensive than that of the end-effector type. Exoskeleton devices are outfitted with programmable drives or passive elements that move the knees and hips during the phases of gait [6]. Examples of the exoskeleton type of device are the Walkbot (P&S Mechanics, Seoul, Korea) and the Lokomat (Hocoma AG, Zurich, Switzerland).

In this manuscript, we used a Cochran search using keywords, including robot-assisted gait training, end-effector type, and exoskeleton type, to summarize the past 10 years of research concerning both end-effector and exoskeleton types of gait robot devices. The current status of robot-assisted therapy in stroke rehabilitation was discussed.

END-EFFECTOR TYPE OF ROBOT-ASSISTED GAIT TRAINING

The results of 10 randomized controlled trials that investigated end-effector robot gait training in stroke patients are summarized in Table 1. Three studies compared therapeutic effects on motor recovery, gait function, and balance between a combination of the robot-assisted gait training and conventional gait training and conventional gait training alone in patients with chronic stroke (> 6 to 12 months) [7-9]. Combined robotic and conventional gait training produced greater improvements in gait function than did conventional gait training alone. Similarly, combined robotic and conventional gait training yielded a superior effect on gait function, balance, and activities of daily living than did conventional gait training in patients with subacute stroke (< 6 weeks to 6 months). These collective findings

Table 1. End-effector type of robot-assisted gait training

Authors	Robotic device	No. of subjects	Stroke stage	Treatment intensity	Outcome measures	Additional therapy	Summary of results
Tong et al. [20]	Gait trainer	46	Subacute	5 times a week for 4 weeks, 20 minutes	5MWT, EMS, BBS, FAC, MI leg subscale, FIM, BI	Functional electrical stimulation	More effective
Dias et al. [7]	Gait trainer	40	Chronic	5 times a week for 4 weeks, 40 minutes	MI, TMS, mASS, BBS, RMI, FMA, FAC, BI, 10MWT, TUG, 6MWT, step tests	-	No difference
Pohl et al. [21]	Gait trainer	155	Subacute	5 times a week for 4 weeks, 20 minutes	FAC, BI, RMI, MI	-	More effective
Ng et al. [22]	Gait trainer	54	Subacute	5 times a week for 4 weeks, 20 minutes	FAC, MI, BBS, 5MWT, BI, EMS, FIM, MMSE	Functional electrical stimulation	More effective
Peurala et al. [23]	Gait trainer	56	Subacute	5 times a week for 3 weeks, 20 minutes	FAC, 10MWT, 6MWT, BI, BMI, MMAS, MRS, RMAS, SSS	-	More effective
Morone et al. [24]	Gait trainer	48	Subacute	5 times a week for 4 weeks, 20 minutes	FAC, 10MWT, MI, 6MWT, RMI, AS, BI, CNS, MMSE, RS, TCT	-	More effective
Geroin et al. [8]	Gait trainer	30	Chronic	5 times a week for 2 weeks, 50 minutes	FAC, 10MWT, MI, 6MWT, RMI, ESS, MMSE, Spatiotemporal Gait Parameters, MAS	Transcranial direct current stimulation	More effective
Conesa et al. [25]	Gait trainer	103	Subacute	5 times a week for 4 weeks, 20–40 minutes (tolerably)	FAC, 10MWT, TBS, TGS	-	Improved
Hesse et al. [26]	G-EO	30	Subacute	5 times a week for 4 weeks, 30 minutes	FAC, RMI, 10MWT, MI	-	More effective
Picelli et al. [9]	G-EO	22	Chronic	5 times a week for 4 weeks, 30 minutes	6MWT, MAS, TGS, TSA	Botulinum toxin type A	More effective

5MWT, 5-meter walk test; EMS, Elderly Mobility Scale; BBS, Berg Balance Scale; FAC, Functional Ambulatory Category; MI, Motricity Index; FIM, Functional Independence Measure; BI, Barthel Index; TMS, Toulouse Motor Scale; mASS, modified Ashworth Spasticity Scale; RMI, Rivermead Mobility Index; FMA, Fugl-Meyer Assessment; 10MWT, 10-meter walk test; TUG, Timed Up and Go; 6MWT, 6-minute walk test; MMSE, Mini-Mental State Examination; MMAS, Modified Motor Assessment Scale; MRS, Modified Ranking Scale; RMAS, Rivermead Motor Assessment Scale; SSS, Scandinavian Stroke Scale; AS, Ashworth Scale; CNS, Canadian Neurological Scale; RS, Rankin Scale; TCT, Trunk Control Test; ESS, European Stroke Scale; MAS, Modified Ashworth Scale; TBS, Tinetti Balance Scale; TGS, Tinetti Gait Scale.

suggest that robot-assisted gait training provides an additive effect to conventional gait training in patients with hemiparetic stroke, regardless of the stroke phase condition.

EXOSKELETON TYPE OF ROBOT-ASSISTED GAIT TRAINING

Table 2 presents the summary of 11 randomized controlled trials that compared the effects of exoskeleton robot-assisted gait training with conventional gait training on motor recovery, gait function, and balance in hemiparetic stroke. Mayr et al. [10] and Husemann et al. [11] reported greater augmented effects from combined exoskeleton robot-assisted gait training combined with conventional gait training compared with conventional gait training alone in 10 subacute stroke patients. Hornby et al. [12] conducted a randomized controlled study that compared the effects of exoskeleton robot-assisted gait training and manual facilitation using an assist-as-needed paradigm on gait function in patients with chronic stroke. Moreover, Hidler et al. [13] also conducted a multicenter randomized trial that investigated the usefulness of Lokomat robot-assisted therapy in 72 patients with subacute stroke and found less effective in the 6-minute walk test (6MWT) and Functional Ambulation Category (FAC) tests than the conventional gait training. Similarly, Hornby et al. [12] found that Lokomat robot-assisted therapy in 62 patients with chronic stroke was not superior to the conventional gait training. Such inconsistent results in the Lokomat robot-assisted studies may result from different experimental design and testing methods utilized [10], lack of volitional neuromuscular control [14], restricted pelvic and trunk movement control [15,16], arm swing, as well as altered acceleration and deceleration from pre-swing to initial contact [17].

https://doi.org/10.12786/bn.2017.10.e9

Table 2. Exoskeleton type of robot-assisted gait training

Authors	Robotic device	No. of subjects	Stroke stage	Treatment intensity	Outcome measures	Additional therapy	Summary of results
Mayr et al. [10]	Lokomat	16	Subacute	5 times a week for 6 weeks, 30 minutes	EWS, RMAS, 10MWT, 6MWT, MI, MRC, AS	-	More effective
Husemann et al. [11]	Lokomat	32	Subacute	5 times a week for 4 weeks, 30 minutes	FAC, 10MWT, MI, BI, MRC, Spatiotemporal Gait Parameters, MAS	-	More effective
Hornby et al. [12]	Lokomat	62	Chronic	Total 12 sessions, 30 minutes	SSFWS, 6MWT, mEFAP, BBS, FAI, Physical SF-36	-	Less effective
Schwartz et al. [27]	Lokomat	67	Subacute	3 times a week for 6 weeks, 30 minutes	FAC, NIHSS, FIM, SAS, 10MWT, 2MWT, TUG, Number of Climbed Stairs	-	More effective
Hidler et al. [13]	Lokomat	72	Subacute	Total 24 sessions, 60 minutes	6MWT, BBS, FAC, NIHSS, Motor Assessment Scale, RMI, FAI, SF-36	-	Less effective
Westlake and Patten [28]	Lokomat	16	Chronic	3 times a week for 4 weeks, 30 minutes	SSFWS, 6MWT, FMA, BBS, SPPB	-	More effective
Chang et al. [29]	Lokomat	37	Subacute	5 times a week for 2 weeks, 40 minutes	FAC, MI, FMA, aerobic capacity, cardiovascular response, ventilatory response	-	No difference
van Nunen et al. [30]	Lokomat	30	Subacute	2 times a week for 8 weeks, 60 minutes	10MWT, FAC, BBS, FMA, MI, RMI, TUG, maximal voluntary isometric torque	-	No difference
Bang and Shin [31]	Lokomat	18	Chronic	5 times a week for 5 weeks, 60 minutes	Spatiotemporal Gait Parameters, BBS, ABC	-	More effective
Taveggia et al. [32]	Lokomat	28	Subacute	5 times a week for 5 weeks, 30 minutes	6MWT, 10MWT, FIM, SF-36, TBS, TGS	-	More effective in functional independence and gait speed, less effective in gait endurance
Kim et al. [33]	Walkbot	30	Subacute	5 times a week for 4 weeks, 40 minutes	FAC, BBS, MBI, MAS, EuroQol-5 dimension	-	More effective in balance and gait function

EWS, EU-Walking Scale; RMAS, Rivermead Motor Assessment Scale; 10MWT, 10-meter walk test; 6MWT, 6-minute walk test; MI, Motricity Index; MRC, Medical Research Council; AS, Ashworth Scale; FAC, Functional Ambulatory Category; BI, Barthel Index; MAS, Modified Ashworth Scale; SSFWS, Self-selected and fast walking speed; mEFAP, modified Emory Functional Ambulation Profile; BBS, Berg Balance Scale; FAI, Frenchay Activities Index; NIHSS, National Institutes of Health Stroke Scale; FIM, Functional Independence Measure; SAS, Stroke Activity Scale; 2MWT, 2-minute walk test; TUG, Timed Up and Go; RMI, Rivermead Mobility Index; FMA, Fugl-Meyer Assessment; SPPB, short physical performance battery; ABC, activities-specific balance confidence; TBS, Tinetti Balance Scale; TGS, Tinetti Gait Scale; MBI, modified Barthel Index.

CONCLUSION

The present review highlights current clinical evidence regarding exoskeleton and end-effector robot-assisted gait training approaches in subacute and chronic stroke patients. A recent Cochrane review [18] reported superior benefits with robot-assisted gait training in stroke rehabilitation. However, the types of robot-assisted gait training devices and their clinical effects are undetermined. Therefore, our review has focused on the types of robot-assisted gait training devices and their clinical effects in robotic assisted gait training.
A meta-analysis of robot-assisted gait training studies is challenging owing to diverse robotic devices, heterogeneous subject characteristics, and varying experimental designs. Therefore, the present review attempted to provide clinical evidence as to which types of exoskeleton type or end-effector type devices are more effective for stroke rehabilitation and locomotor recovery and function. Taken together, the findings showed that combined robot-assisted gait training was advantageous in stroke rehabilitation, as it offers additive special therapeutic effects that were not afforded by conventional therapy alone. Most importantly, the robot-assisted gait training paradigm renders intensive, repetitive, accurate kinematic feedback and symmetrical gait practice, while reducing therapist labor, which is often not

affordable in current stroke rehabilitation care [19]. Furthermore, the current robot-assisted gait training incorporates virtual or augmented reality to motivate patients, as well as to provide fun and ecologically valid gait training. Since the additive effect of robot-assisted gait training is well established, a prospective study is warranted to determine if robot-assisted gait training is superior to conventional stroke locomotor rehabilitation alone or robot-assisted gait training combined with conventional gait training. It would be of great interest to examine the effects of repetitive robot-assisted gait training on neuroplasticity and associated locomotor recovery in a stroke population.

REFERENCES

1. Hajek VE, Gagnon S, Ruderman JE. Cognitive and functional assessments of stroke patients: an analysis of their relation. Arch Phys Med Rehabil 1997;78:1331-1337.
   PUBMED | CROSSREF
2. Lord SE, Rochester L. Measurement of community ambulation after stroke: current status and future developments. Stroke 2005;36:1457-1461.
   PUBMED | CROSSREF
3. Roth EJ, Merbitz C, Mroczek K, Dugan SA, Suh WW. Hemiplegic gait. Relationships between walking speed and other temporal parameters. Am J Phys Med Rehabil 1997;76:128-133.
   PUBMED | CROSSREF
4. Nudo RJ, Wise BM, SiFuentes F, Milliken GW. Neural substrates for the effects of rehabilitative training on motor recovery after ischemic infarct. Science 1996;272:1791-1794.
   PUBMED | CROSSREF
5. Haavik H, Murphy B. The role of spinal manipulation in addressing disordered sensorimotor integration and altered motor control. J Electromyogr Kinesiol 2012;22:768-776.
   PUBMED | CROSSREF
6. Hesse S, Waldner A, Tomelleri C. Innovative gait robot for the repetitive practice of floor walking and stair climbing up and down in stroke patients. J Neuroeng Rehabil 2010;7:30.
   PUBMED | CROSSREF
7. Dias D, Laíns J, Pereira A, Nunes R, Caldas J, Amaral C, et al. Can we improve gait skills in chronic hemiplegics? A randomised control trial with gait trainer. Eura Medicophys 2007;43:499-504.
   PUBMED
8. Geroin C, Picelli A, Munari D, Waldner A, Tomelleri C, Smania N. Combined transcranial direct current stimulation and robot-assisted gait training in patients with chronic stroke: a preliminary comparison. Clin Rehabil 2011;25:537-548.
   PUBMED | CROSSREF
9. Picelli A, Bacciga M, Melotti C, LA Marchina E, Verzini E, Ferrari F, et al. Combined effects of robot-assisted gait training and botulinum toxin type A on spastic equinus foot in patients with chronic stroke: a pilot, single blind, randomized controlled trial. Eur J Phys Rehabil Med 2016;52:759-766.
10. Mayr A, Kofler M, Quirbach E, Matzak H, Fröhlich K, Saltuari L. Prospective, blinded, randomized crossover study of gait rehabilitation in stroke patients using the Lokomat gait orthosis. Neurorehabil Neural Repair 2007;21:307-314.
    PUBMED | CROSSREF
11. Husemann B, Müller F, Krewer C, Heller S, Koenig E. Effects of locomotion training with assistance of a robot-driven gait orthosis in hemiparetic patients after stroke: a randomized controlled pilot study. Stroke 2007;38:349-354.
    PUBMED | CROSSREF
12. Hornby TG, Campbell DD, Kahn JH, Demott T, Moore JL, Roth HR. Enhanced gait-related improvements after therapist- versus robotic-assisted locomotor training in subjects with chronic stroke: a randomized controlled study. Stroke 2008;39:1786-1792.
    PUBMED | CROSSREF
13. Hidler J, Nichols D, Pelliccio M, Brady K, Campbell DD, Kahn JH, et al. Multicenter randomized clinical trial evaluating the effectiveness of the Lokomat in subacute stroke. Neurorehabil Neural Repair 2009;23:5-13.
    PUBMED | CROSSREF

14. Yen CL, Wang RY, Liao KK, Huang CC, Yang YR. Gait training induced change in corticomotor excitability in patients with chronic stroke. Neurorehabil Neural Repair 2008;22:22-30.
PUBMED | CROSSREF

15. Gottschall JS, Kram R. Energy cost and muscular activity required for propulsion during walking. J Appl Physiol (1985) 2003;94:1766-1772.

16. Israel JF, Campbell DD, Kahn JH, Hornby TG. Metabolic costs and muscle activity patterns during robotic- and therapist-assisted treadmill walking in individuals with incomplete spinal cord injury. Phys Ther 2006;86:1466-1478.
PUBMED | CROSSREF

17. Regnaux JP, Saremi K, Marehbian J, Bussel B, Dobkin BH. An accelerometry-based comparison of 2 robotic assistive devices for treadmill training of gait. Neurorehabil Neural Repair 2008;22:348-354.
PUBMED | CROSSREF

18. Mehrholz J, Elsner B, Werner C, Kugler J, Pohl M. Electromechanical-assisted training for walking after stroke. Cochrane Database Syst Rev 2013:CD006185.
PUBMED

19. Hornby TG, Zemon DH, Campbell D. Robotic-assisted, body-weight-supported treadmill training in individuals following motor incomplete spinal cord injury. Phys Ther 2005;85:52-66.
PUBMED

20. Tong RK, Ng MF, Li LS. Effectiveness of gait training using an electromechanical gait trainer, with and without functional electric stimulation, in subacute stroke: a randomized controlled trial. Arch Phys Med Rehabil 2006;87:1298-1304.
PUBMED | CROSSREF

21. Pohl M, Werner C, Holzgraefe M, Kroczek G, Mehrholz J, Wingendorf I, et al. Repetitive locomotor training and physiotherapy improve walking and basic activities of daily living after stroke: a single-blind, randomized multicentre trial (DEutsche GAngtrainerStudie, DEGAS). Clin Rehabil 2007;21:17-27.
PUBMED | CROSSREF

22. Ng MF, Tong RK, Li LS. A pilot study of randomized clinical controlled trial of gait training in subacute stroke patients with partial body-weight support electromechanical gait trainer and functional electrical stimulation: six-month follow-up. Stroke 2008;39:154-160.
PUBMED | CROSSREF

23. Peurala SH, Airaksinen O, Huuskonen P, Jäkälä P, Juhakoski M, Sandell K, et al. Effects of intensive therapy using gait trainer or floor walking exercises early after stroke. J Rehabil Med 2009;41:166-173.
PUBMED | CROSSREF

24. Morone G, Bragoni M, Iosa M, De Angelis D, Venturiero V, Coiro P, et al. Who may benefit from robotic-assisted gait training? A randomized clinical trial in patients with subacute stroke. Neurorehabil Neural Repair 2011;25:636-644.
PUBMED | CROSSREF

25. Conesa L, Costa Ú, Morales E, Edwards DJ, Cortes M, León D, et al. An observational report of intensive robotic and manual gait training in sub-acute stroke. J Neuroeng Rehabil 2012;9:13.
PUBMED | CROSSREF

26. Hesse S, Tomelleri C, Bardeleben A, Werner C, Waldner A. Robot-assisted practice of gait and stair climbing in nonambulatory stroke patients. J Rehabil Res Dev 2012;49:613-622.
PUBMED | CROSSREF

27. Schwartz I, Sajin A, Fisher I, Neeb M, Shochina M, Katz-Leurer M, et al. The effectiveness of locomotor therapy using robotic-assisted gait training in subacute stroke patients: a randomized controlled trial. PM R 2009;1:516-523.
PUBMED | CROSSREF

28. Westlake KP, Patten C. Pilot study of Lokomat versus manual-assisted treadmill training for locomotor recovery post-stroke. J Neuroeng Rehabil 2009;6:18.
PUBMED | CROSSREF

29. Chang WH, Kim MS, Huh JP, Lee PK, Kim YH. Effects of robot-assisted gait training on cardiopulmonary fitness in subacute stroke patients: a randomized controlled study. Neurorehabil Neural Repair 2012;26:318-324.
PUBMED | CROSSREF

30. van Nunen MP, Gerrits KH, Konijnenbelt M, Janssen TW, de Haan A. Recovery of walking ability using a robotic device in subacute stroke patients: a randomized controlled study. Disabil Rehabil Assist Technol 2015;10:141-148.
PUBMED | CROSSREF

31. Bang DH, Shin WS. Effects of robot-assisted gait training on spatiotemporal gait parameters and balance in patients with chronic stroke: a randomized controlled pilot trial. NeuroRehabilitation 2016;38:343-349.
PUBMED | CROSSREF

32. Taveggia G, Borboni A, Mulé C, Villafañe JH, Negrini S. Conflicting results of robot-assisted versus usual gait training during postacute rehabilitation of stroke patients: a randomized clinical trial. Int J Rehabil Res 2016;39:29-35.
PUBMED | CROSSREF

33. Kim SY, Yang L, Park IJ, Kim EJ, JoshuaPark MS, You SH, et al. Effects of innovative WALKBOT robotic-assisted locomotor training on balance and gait recovery in hemiparetic stroke: a prospective, randomized, experimenter blinded case control study with a four-week follow-up. IEEE Trans Neural Syst Rehabil Eng 2015;23:636-642.
PUBMED | CROSSREF