J Rehabil Med 2007; 39: 580–582

SHORT COMMUNICATION

ROBOT-MEDIATED UPPER LIMB PHYSIOTHERAPY FOR PATIENTS WITH SPASTIC HEMIPARESIS: A PRELIMINARY STUDY

Gabor Fazekas[1,2], Monika Horvath[1,2], Tibor Troznai[1] and Andras Toth[3]

From the [1]National Institute for Medical Rehabilitation, [2]Szent Janos Hospital and [3]Budapest University of Technology and Economics, Budapest, Hungary

Objective: **To investigate the clinical usefulness of the REHAROB Therapeutic System, which provides passive robot-mediated physiotherapy for patients with spastic hemiparesis.**
Design: **Controlled, randomized, preliminary study.**
Patients and methods: **Thirty patients with hemiparesis as a consequence of upper motor neurone lesion were divided randomly into 2 groups: robotic and control. Subjects from both groups received 30 minutes of Bobath therapy sessions on 20 consecutive work days. Members of the robotic group received an additional 30 minutes of robot-mediated therapy on the same days. The clinical status of each patient was assessed before the first session and at the end of the programme. The difference in the scores was statistically evaluated by *t*-test for dependent variables in case of parametric data and Friedman's test in case of non-parametric data.**
Results: **The majority of the parameters measured improved in both groups, but modified Ashworth score of shoulder adductors and elbow flexors showed a statistically significant change only in the robotic group.**
Conclusion: **The results suggest that it could be useful to supplement traditional physiotherapy with this form of robot-mediated therapy. Clinical investigation of a higher number of patients is planned in the near future.**

Key words: spasticity, hemiparesis, robotics, stroke, traumatic brain injury.

J Rehabil Med 2007; 39: 580–582

Correspondence address: Gabor Fazekas, National Institute for Medical Rehabilitation, Szanatorium str. 19th, 1528 Budapest, Hungary. E-mail: fazekas123@t-online.hu

Submitted April 24, 2006; accepted March 9, 2007

INTRODUCTION

Stroke, traumatic brain injury and some other conditions often cause spastic hemiparesis. Spasticity is often an important problem in these cases. Spasticity is velocity- and acceleration-dependent. It has been suggested that performing exercises at a slow and constant velocity is beneficial in reducing spasticity (1). This might be managed more accurately by a robot than by a person. The use of robots is a relatively new trend for improving rehabilitation programmes (2, 3). The US Mirror Image Movement Enabler (MIME) and the Massachusetts Institute of Technology (MIT)-Manus robots provide goal-directed exercise training. Studies using these robots have showed that repetitive exercise training could improve motor abilities even in the chronic stage following stroke (4–6). In the REHAROB (robotic rehabilitation system for upper limb motion therapy for the disabled) project of the 5th Framework Programme of the European Union, a robotic rehabilitation system was developed to support upper limb (shoulder and elbow) physiotherapy of patients with spastic hemiparesis. The REHAROB Therapeutic System uses 2 industrial robot arms to exercise the patient's upper limb. The system can be adapted easily to suit patient's individual requirements.

An initial clinical trial was carried out to gain experience of the equipment (7). Twelve participants were subjected to a total of 240 robot-mediated sessions of physiotherapy. Some parts of the system were then modified (8). To investigate the effectiveness of the system a controlled clinical study was designed. In this preliminary trial (named Fiziorobot study) the aim was to investigate the robot-mediated therapy with a wide range of patients: left- and right-sided hemiparesis, men

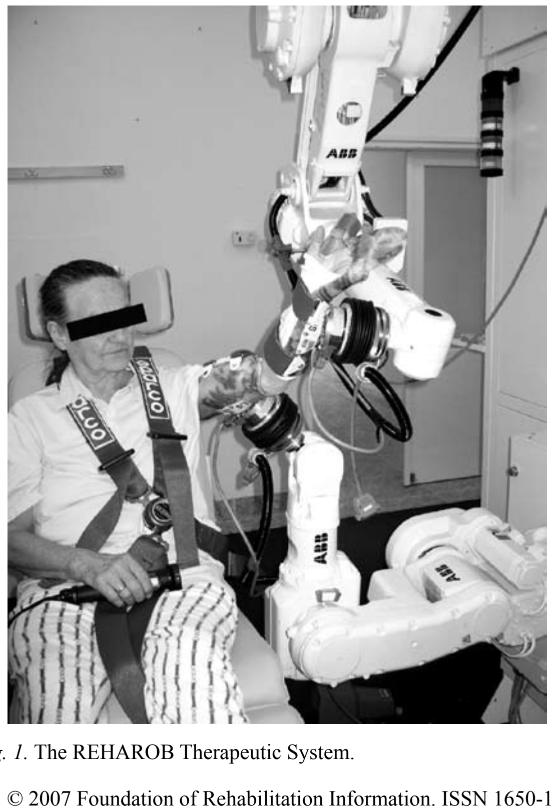

Fig. 1. The REHAROB Therapeutic System.

 ISSN 1650-1977
doi: 10.2340/16501977-0087

Table I. *Main data for the subjects*

	Control	Robotic
All	15	15
Female	5	8
Male	10	7
Traumatic brain injury	6	2
Stroke	9	13
Hemipareis		
Left	6	7
Right	9	8
Age, mean (range) (years)	55.9 (28–77)	56.6 (28–82)
Time since onset (months)	9.5 (1.1–44)	23.2 (1.2–87)

and women, young and older subjects, patients after stroke and traumatic brain injury.

PATIENTS AND METHODS

The REHAROB Therapeutic System involves 2 unmodified industrial robots (Fig. 1). The robot arms are connected to the patient's upper arm and forearm through instrumented orthoses. The robot-mediated therapy comprises 3 main steps: the physiotherapist teaches the robots a series of exercises (i.e. the physiotherapist programs the robots). The physiotherapist then edits a complex therapy programme using these exercises, determining the order and repetition number of the exercises. Finally, the robots execute the complex therapy programme. In this way the REHAROB Therapeutic System provides passive shoulder and elbow physiotherapy. The physiotherapist can choose exercises from any therapeutic school (Bobath, Kabat, etc.). The detailed operation of REHAROB and the safety measures involved have been described previously (9).

The clinical trial was designed in compliance with the Declaration of Helsinki. The Investigation Plan was approved by both the local ethics committee and the National Scientific and Research Ethics Committee. All subjects signed the informed consent.

A total of 30 patients with hemiparesis as a consequence of upper motor neurone lesion due to stroke or traumatic brain injury (confirmed by computerized tomography or magnetic resonance imaging) were divided randomly into 2 groups (15–15 patients). The main subject data are shown in Table 1. Subjects in both groups received 30 minutes of Bobath therapy sessions on 20 consecutive work days. Members of the robotic group received an additional 30 minutes of robot-mediated therapy on the same 20 days. The clinical status of each patient was assessed before the first therapeutic session, after the 10th event (intermediate assessment) and at the end of the programme. The measured parameters were as follows: modified Ashworth score of shoulder adductors and elbow flexors (10); range of motion of shoulder and elbow; the Fugl-Meyer scale – shoulder and elbow subsection (11); Rivermead Motor Assessment (RMA) – arm score; Functional Independence Measure (FIM™) – self-care subsection (12). The assessment was performed by a blinded physiotherapist.

Statistics

Statistical analysis was performed using SPSS software (package 14.0). The difference in the scores between the initial and final assessments were statistically evaluated by *t*-test for dependent variables in the case of parametric data, and by Friedman's test in the case of non-parametric data. Differences were considered significant at the level of $p \leq 0.05$.

RESULTS

The results are presented in Table II. Both groups showed improvement in most fields. In controls the improvement was statistically significant ($p < 0.05$) regarding Fugl-Meyer shoulder – elbow subsection, active range of elbow flexion, RMA – arm score and FIM™ – self-care. Patients in the robotic group showed significant improvement in the same fields as well as in the modified Ashworth score for shoulder adductors and elbow flexors. We found no significant improvement in shoulder girdle anteflexion of either groups. FIM™ – self-care score improved more remarkably in controls.

The patients received a total of 150 h of robot-mediated therapy. No adverse events occurred.

Table II. *Results when comparing the robot-mediated therapy (n = 15) with controls (n = 15)*

	Possible range	Group	Median Initial – Final assessment	Mean Initial – Final assessment	Value of significance*
Rivermead arm score	0–15	Robotic	3–4	3.0–5.33	**0.0001**
		Control	3–6	4.93–6.8	**0.0001**
Modified Ashworth of shoulder adductors	0–5	Robotic	2–1	1.93–1.2	**0.011**
		Control	2–2	1.67–1.47	0.564
Modified Ashworth of elbow flexors	0–5	Robotic	3–2	2.87–2.13	**0.021**
		Control	3–2	2.13–2.13	0.705
Fugl-Meyer shoulder-elbow subsection	0–36	Robotic	18–25	17.67–23.07	**0.0001**
		Control	24–26	21.73–24.33	**0.0001**
ROM – S	0–180°	Robotic	99–97	84.33–93.47	0.145
		Control	108–108	98.93–98.8	0.987
ROM – E	0–140°	Robotic	24–91	50.6–76.33	**0.036**
		Control	80–103	70.0–86.73	**0.015**
FIM™ – self-care	6–42	Robotic	36–36	29.8–33.87	**0.014**
		Control	29–36	25.8–34.53	**0.001**

*p-values < 0.05 are shown in bold type.ROM – S: active range of shoulder-girdle anteflexion; ROM – E: active range of elbow flexion; FIM™: Functional Independence Measure.
Rivermead, Ashworth, Fugl-Meyer and FIM were calculated by Friedman's test for related samples, ROM–S and E were calculated by *t*-test for dependent samples.

DISCUSSION

The REHAROB Therapeutic System provides passive physiotherapy including shoulder and elbow movements for patients with spastic hemiparesis. The therapy programme is planned individually, the repetition number of the exercises can be determined by the physiotherapist and it is not limited by therapist fatigue. The system is able to execute complex exercises in the full range of shoulder and elbow movements.

The aim of this pilot study was to investigate whether this kind of robot-mediated therapy provides advantages for the patients with spastic hemiparesis, if their traditional therapy is supplemented with the robot-mediated one.

Thirty patients with spastic hemiparesis were divided randomly into 2 groups. Both received neurodevelopmental therapy, and the robotic group also received robot-mediated therapy. Seven parameters were assessed before and after the therapy programme. The majority of parameters improved in both groups, but the modified Ashworth score for shoulder adductors and elbow flexors showed a statistically significant change only in the robotic group. The self-care score of FIM™ started from a lower value and reached a better outcome in the controls. A possible reason for this could be that the positive change in the FIM™ score was not exclusively due to the improvement in the affected upper limb motor impairment. (Nevertheless the change in this score in both groups proved to be significant.) It appears that the robotic therapy was beneficial in reducing spasticity, however from this analysis no conclusion can be drawn about its effect on active movements or activities of daily living.

The results suggest that this form of robot-mediated therapy could usefully supplement traditional methods.

The exercises executed by REHAROB are different from those provided by MIT-Manus or MIME systems, which set their sights on goal-directed movements. REHAROB represents another idea: executing exercises slowly and with constant velocity in a high repetition number so as to decrease spasticity and increase range of motion of shoulder and elbow joints. The final aim of each method is to contribute to a better functional outcome. It seems that the role of the robot-mediated therapy is not to replace the physiotherapist, but rather to widen the treatment options (13).

The authors believe that the results of this preliminary study are encouraging: the REHAROB Therapeutic System works reliably and benefits patients who receive the robot-mediated therapy. Nevertheless, further clinical investigation on a higher number of patients is needed to reinforce these preliminary results.

ACKNOWLEDGEMENTS

The development of the REHAROB Therapeutic System was sponsored under the 5th Framework Programme of the European Commission by the project IST-1999-13109. The project partners were: Budapest University of Technology and Economics, Hungary; National Institute for Medical Rehabilitation, Hungary; University of Wales Cardiff, UK; University of Rousse, Bulgaria; and Zebris Medizintechnik GmbH, Germany. The Fiziorobot project was supported by the Hungarian Medical Research Council under grant 073/2003.

REFERENCES

1. Bobath B, editor. Adult hemiplegia: evaluation and treatment. 3rd edn. Oxford: Butterworth-Heinemann; 1990, p. 13.
2. Lum P, Reinkensmeyer D, Mahoney R, Rymer WZ, Burgar C. Robotic devices for movement therapy after stroke: current status and challenges to clinical acceptance. Top Stroke Rehabil 2002; 8: 40–53.
3. Coote S, Stokes EK. Robot mediated therapy: attitudes of patients and therapists towards the first prototype of the GENLE/s system. Technol Disabil 2003: 27–34.
4. Lum PS, Burgar CG, Shor CT, Majmundar M, Van der Loos HFM. Robot-assisted movement training compared with conventional therapy techniques for the rehabilitation of upper-limb motor function after stroke. Arch Phys Med Rehabil 2002; 83: 952–959.
5. Ferraro M, Palazzolo JJ, Krol J, Krebs HI, Hogan N, Volpe BT. Robot-aided sensorimotor arm training improves outcome in patients with chronic stroke. Neurology 2003; 61: 1604–1607.
6. Fasoli SE, Krebs HI, Stein J, Frontera WR, Hughes R, Hogan N. Robotic therapy for chronic motor impairments after stroke: follow-up results. Arch Phys Med Rehabil 2004; 85: 1106–1111.
7. Toth A, Fazekas G, Arz G, Jurak M, Horvath M. Passive robotic movement therapy of the spastic hemiparetic arm with REHAROB: report of the first clinical test and the follow-up system improvement. In: Proceedings of IEEE 9th International Conference on Rehabilitation Robotics in Chicago, IL. Madison, USA (WI): Omnipress 2005, p. 127–130.
8. Fazekas G, Horvath M, Toth A. A novel robot training system designed to supplementary upper limb physiotherapy of patients with spastic hemiparesis. Int J Rehabil Res 2006; 29: 251–254.
9. Toth A, Arz G, Fazekas G, Bratanov D, Zlatov N. Post stroke shoulder-elbow physiotherapy with industrial robots. In: Bien ZZ, Stefanov D, editors. Advances in rehabilitation robotics, human-friendly technologies on movement assistance and restoration for people with disabilities. Berlin: Springer Publishing; 2004: p. 391–411.
10. Bohannon RW, Smith MD. Interrater reliability of a Modified Ashworth Scale of muscle spasticity. Phys Ther 1987; 67: 206–207.
11. Fugl-Meyer AR. Post-stroke hemiplegia assessment of physical properties. Scand J Rehabil Med Suppl 1980; 7: 85–93.
12. Hamilton BB, Laughlin JA, Fiedler RC, Granger CV. Interrater reliability of the 7-level functional independence measure. Scand J Rehabil Med 1994; 25: 115–119.
13. Hidler J, Nichols D, Pelliccio M, Brady K. Advances in the understanding and treatment of stroke impairment using robotic devices. Top Stroke Rehabil 2005; 12: 22–35.