# Ideals and Realities in Robot-Mediated Stroke Rehabilitation

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## Abstract
Through an observational research on robot-mediated therapy sessions, in this study, we try to understand the functional limitation of the rehabilitation robot from the perspective of human-robot interaction, and examine how it affects the role and practice of therapists in the routine rehabilitation therapy. With qualitative data from observation and interviews, we analyze the experience of therapists in their actual work context and their view on the use and effectiveness of the robot. We suggest potential research directions to enhance the quality of the robot rehabilitation.

## Author Keywords
Rehabilitation Robots; Stroke; Physical Therapy; Occupational Therapy; Upper Extremity; Lower Extremity; Lokomat; Armeo; Neuro-X; Walkbot

## ACM Classification Keywords
H.m [Information Interfaces and Presentation (e.g., HCI)]: Miscellaneous; J.3 [Life and Medical Sciences]: Health

## Introduction
In this research, we investigate the functional limitation of the rehabilitation robot and how it defines the role of therapists in the routine robot-mediated therapy session by addressing two underexamined aspects in past studies. First, the function of robots being employed in routine clinical set-

tings is limited to physically assisting the limb movement of the patient. Second, despite the low adoption rate in hospitals, few researchers have investigated the practical challenges that are experienced and perceived by therapists when using these robots in actual therapy sessions. From the perspective of the human-robot interaction, we attempt to understand the function of the robot and its feasibility in the context of the interaction between the robot, therapist and patient. Through an observational research on the actual therapy sessions in 5 hospitals in South Korea, we analyze how the use of robot affects the routine practice of therapists and redefines the conventional practice that therapists perform during the routine therapy session. We conclude with a discussion on potential future research directions for improving the effectiveness of the robot rehabilitation in practice.

## Background

For the past decades, the potential of using the physically assistive robot in the rehabilitation therapy has received increasing attention as a means to enable the longitudinal and intensive rehabilitation for those who experienced stroke. Despite varying design choices, the primary function of the robot is to help complete the movement of the patient otherwise impossible by the patient alone [6, 5], which imitates the style of the skilled therapist's *hands-on* physical assistance in guiding the limb movement of the patient.

There is a large volume of empirical evidence that the robot-mediated rehabilitation therapy may lead to motor recovery that is observable in standardized assessment tools, such as Fugl-Meyer Assessment (FMA) [1] and Wolf Motor Function Test (WMFT) [7]. One notable multisite controlled experiment suggests that the patient who exercises his upper extremity with the InMotion Arm robot (Interactive Motion Technologies) [2] may show significantly better improvement in FMA and WMFT than the person who receives usual care [4].

Despite encouraging results, such studies focus on validating the clinical efficacy of the implemented function against the lack of it or against a similar function executed by the human therapist in a highly controlled experiment. However, the function of investigation often represents a subset of what therapists deem necessary to maintain the quality of the rehabilitation therapy in practice. In addition, the functional limitation of the robot and additional functions that need to be researched are not adequately discussed in such controlled empirical studies.

In this study, we try to verify the challenges of using the rehabilitation robot in actual practice by paying attention to the lived experience of therapists on their use of the robot and how they evaluate the effectiveness of the robot in their routine therapy sessions.

## Methodology

This study is based on the observational field study to pursue the context- and subject-based knowledge of complicated factors to limit the adoption of the robot in practice, which has not been investigated in controlled clinical research. Specifically, we conduct observation in 5 hospitals that employ rehabilitation robots for their routine therapies, supplemented by semi-structured interviews with 10 therapists who are affiliated to the hospitals.

**Data Collection** We constrain our focus on commercially available actuated assistive or resistive devices that are being used in regular clinical settings for exercises of any body parts. For recruitments, private rehabilitation hospitals that own and operate rehabilitation robots on a daily basis are considered as potential study sites. University hospitals

| **Hospital** | **A** | **B** | **C** | **D** | **E** |
|---|---|---|---|---|---|
| Visited Date(s) | 2016/8/4 | 2016/6/2 | 2016/8/26-27 | 2016/7/28 | 2016/11/19 |
| Robots | 1×Walkbot<br>2×Neuro-X | 1×Lokomat Pro<br>1×Lokomat Nano | 1×Lokomat Pro<br>1×Armeo Spring | 1×Lokomat Pro | 1×Lokomat Pro<br>1×Armeo Power |
| Observation Context | Routine Therapy | Routine Therapy | Training<br>Demonstration | N/A | Demonstration |
| Duration (Video Recording) | 3 hrs (N/A) | 4 hrs (1.5 hrs) | 16 hrs (3.2 hrs) | N/A (N/A) | 1 hr (1 hr) |
| Interviewees | 2 | 4 | 1 | 1 | 2 |
| Duration (Interview) | 3 hrs | 2 hrs | 2 hrs | 2 hrs | 1 hr |

**Table 1:** Overall information of the recruited hospitals and the interviewees

that have a dedicated robot rehabilitation unit are also considered. The list of candidate hospitals was created through online search and the recommendation of peer researchers or therapists, and they were subsequently contacted by phone for the recruitment. A total of 5 institutions (A, B, C, D, and E) have notified their acceptance of either or both the observation and the interview in May, 2016. Upon the hospital's approval, the researchers individually asked each therapist and patient to gain their informed consent for observation and video recording. The recruitment for interview was done in a similar manner. No video recording or interview was conducted without the permission of the therapist and the patient.

Both observation and interview were conducted for 6 days (1-2 days per hospital) from June through November 2016. To understand how the therapists use the robot for the patients with a diverse range of treatment goals, our focus of observation was the routine practice of the therapists and their interaction with the robot and patients to achieve the quality rehabilitation. To understand how the use of robots affects the routine therapy session, we interviewed the therapists individually and asked their personal experience and evaluation of using the robot in their actual therapy practice. Most interviews were conducted during breaks between the therapy sessions and/or during lunch breaks, with a varied duration between 0.5-2 hours per interview. The general information of the hospitals, observations, and the interviewees are summarized in Table 1.

**Data Analysis** The analytical procedure goes as follows. A total of 31 video clips were analyzed by two researchers, focusing on the role and practice of the therapists and their use of robots in the actual clinical setting. A total of 10 interviews directly provide the contextual information needed to analyze how the functionality of those robots facilitates the performance as designed or changes the routine practice or interaction of the therapists.

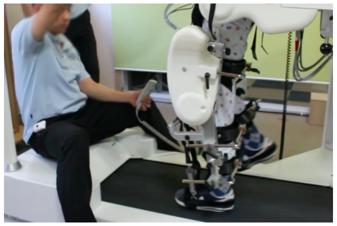

**Figure 1:** The therapist visually examines the stance and the gait pattern of the patient as he lifts her down on the treadmill (Lokomat Pro).

**Figure 2:** The therapist walks around the patient and visually evaluates the overall gait posture (Lokomat Pro).

By doing so, researchers discovered the 4 themes to explain how the use of the robot affects the conventional practice and interaction of therapists in the routine therapy session: 1) the role of therapists; 2) interventions they perform during the interaction with the robot and the patient; 3) subjective evaluation on their role and intervention; 4) and opinion on the quality of the robot-mediated therapy.

## Findings

**Continuous Detailed Human Monitoring** All of the interviewed therapists claimed that it was crucial for them to monitor the quality of the posture and the movement of the patient throughout the robot-mediated therapy session. The commercial rehabilitation robot can indirectly sense the movement of the patient by the force and the torque measured at the implemented sensors, especially the affected limb only in the case of upper limb rehabilitation robots. The therapists point out that this does not capture the necessary information, especially the compensatory behavior by the unaffected limbs of the patient. Hence, it falls under the therapist's responsibility to watch both the posture and the movement of the patient, as well as to check the kinematic data displayed on the screen, if such function is available.

The following list is the commonly observed occasions, which show how therapists monitor the movement quality of the patients.

- For all the robots, the therapist paid significant attention to aligning the patient's limbs with the robot links, especially when attaching the patient to the robot before the beginning of the session.
- While using Lokomat or Walkbot, the therapist lifted down the patient and examined if the imposed body weight support was appropriate by evaluating the overall posture of the patient (Figure 1). Sometimes, the therapist double-checked as he walked around the patient (Figure 2).
- For all the robots, while the patient was executing movements, the therapist checked the posture of the patient's head and the direction of his eye gaze. This monitoring, as many interviewed therapists claimed, inform them of the level of engagement and the fatigue of the patient during the exercise, and thereby help to maintain the quality of exercise.
- For all the robots, the therapist monitored if the patient was recruiting abnormal compensatory movements, such as trunk anterior displacement for the upper extremity exercise and imbalance in the loading response for the lower extremity exercise.
- While using Lokomat and Walkbot, as the patient began to lose his correct posture over time, the therapist needed to monitor this minute change continuously.

**Diverse Intervention Strategies** The rehabilitation robot is designed to support the partial weight of the patient against the gravity and to guide their limb movements. Indeed, it was consistently observed that the therapists relied on this function of the rehabilitation robot in actual practice. The only exception was when the therapist had to transfer the patient from the wheelchair to the robot and back to the wheelchair. However, we found that the therapists still chose to employ a wide range of physical and social intervention strategies to help the patients maintain proper postures, execute movements in a desirable manner and engage in the therapeutic exercise. Indeed, in the Lokomat Pro training that we observed in hospital C, significant amount of time was assigned to the discussion of such strategies and the reasoning behind them.

The following examples from our observation indicate how therapists respond to the abnormal movement of the patient

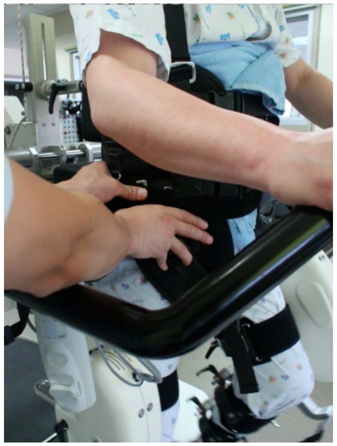

**Figure 3:** The therapist provides physical intervention to the pelvic joint to induce a desired stance and a gait pattern (Lokomat Pro).

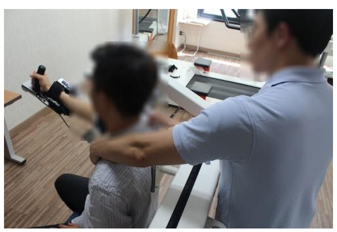

**Figure 4:** To induce a desirable arm reaching movement, the therapist suppresses the compensatory movement of the trunk and taps the exercising shoulder while encouraging its movement through speech instructions (Armeo Spring).

during the exercise.

- For all the robots, in order to help the patient execute the desired exercise movements, the therapist described the movements from the related activities of daily living (ADL) and how the movement should be executed in more detail. If necessary, the therapist gave a demonstration of the instructed movements for patients.
- For all the robots, the therapist restrained certain joint movements or held down the inappropriately activated muscle groups (Figure 3 and 4).
- As the therapy session progressed, the patient often became crouched or leaned backward, creating undesirable body postures. Based on the cognition level of the patient, the therapist chose to provide either physical or social intervention to correct the patient's posture. When the patient became disengaged from the therapy exercise and put down his head or closed his eyes, the therapist called the patient's attention and encouraged him to correct his posture with gentle taps on his shoulder or arms (Figure 4).
- For the lower extremity robots, in order to respond to the abnormal movement of the patient, the therapist used the computer and mechanical interfaces of the rehabilitation robot to change the necessary parameters (Figure 5).

**Physical and Cognitive Burdens** The interviewed therapists agreed that the rehabilitation robot reduced significant amount of their physical burden, especially in terms of the body weight support and the limb movement guidance. However, the therapists still needed to control the robot to make it function in a desired way. In addition, they employed a diverse range of social and physical intervention to keep the therapy session safe and clinically meaningful. This necessitated the presence of the therapists and their continued attention throughout the therapy session. Many therapists claim that they have a very short or even no break between the consecutive robot-mediated therapy sessions, which significantly adds to their physical and cognitive burden and decreases their concentration over time.

**Inconsistent Human Intervention** As discussed above, the therapists were heavily and consistently involved in the entire process of the robot-mediated therapy. Hence, the performance of therapists is a key to improve the quality of the therapy. The interviewed therapists stated that some of the factors that determine their performance included their basic knowledge and experience as therapists, the quantity and quality of training they received in robot-assisted therapy, and their personal dedication or efforts in each therapy session. In addition, it was observed that the number of robots and patients that were assigned to a single therapist also affected the quality of the therapy session. For instance, a therapist had to engage with one patient at a time when he had multiple patients for the upper-extremity therapy. The other patients who did not have the attention of the therapist thus readily recruited compensatory behaviors that might not lead to *true* motor recovery. Lastly, as the interviewed therapists agreed, the quality of the therapy can vary with the skill and mastery of the therapist to operate the robot, even when the rehabilitation robot is used.

## Discussion

Our investigation reveals that the function of the rehabilitation robot is appreciated by therapists as it reduces their workload in the body weight support and the limb movement guidance. However, there exist many physical and social functions that have not been modeled in the design of the rehabilitation robot. To further improve the clinical benefit of the robot rehabilitation, as pointed out by other

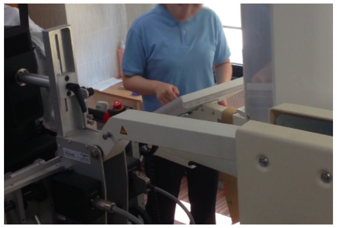

**Figure 5:** When parameters are not set properly, the patient may drop the forefoot during the gait practice. In order to remove such abnormal gait pattern, the therapist adjusts the gait offset parameter using the touch display (Lokomat Pro).

researchers [3], it is important to identify the fundamental components of the ideal therapy practice that can maximize the clinical gain. Then, it is necessary to discuss the roles of the therapist and the robot and how they should coordinate in order to collectively control the quality of the robot-mediated therapy. Subsequently, this should guide the direction of researching and developing the rehabilitation robot. Furthermore, it seems crucial to provide therapists with quality trainings on the use of the robot, which can help them become competent in using the robot early on.

## Conclusion

This extended abstract is the result of our attempt to understand the limited function of the robot and identify additional functions that may be considered to improve the effectiveness of the robot-mediated therapy. For that, we conducted an observational field study and investigated the tasks that the therapists performed to compensate for the limited function of the rehabilitation robot and their perspective during their routine therapy session. We further examined the factors that affected the quality of the robot therapy from the therapists' perspective. Although the robot plays positive roles in the rehabilitation therapy, we learned that various physical and social strategies were not modeled in the contemporary robotic solutions, which require the attention of the research community. We expect our research would guide the direction of researching and developing the rehabilitation robot.

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