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CASE REPORT

A Pilot Trial of Telerehabilitation for Chronic Stroke Survivors: A Case-series Study of Three Individuals

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Background: We designed a telerehabilitation (TR) program for stroke patients based on reports from other countries and adapted the program for use by individual patients. Herein, we describe the clinical courses of three stroke survivors who used the TR program. **Cases:** All three individuals were community-dwelling chronic stroke survivors. Patient 1 (P1) was a 50-year-old man who presented with severe paralysis of the right upper and lower extremities caused by left cerebral hemorrhage. Patient 2 (P2) was a 56-year-old woman who presented with severe paralysis of the left upper and lower extremities caused by right cerebral hemorrhage. Patient 3 (P3) was a 55-year-old man who presented with severe paralysis of the left upper and lower extremities caused by right cerebral hemorrhage. The TR program was conducted through a web conference system that allowed therapists and patients to interact with each other. The intervention consisted of 30-min sessions every 2 weeks for 6 months. The clinical courses and outcomes of the patients differed, but we identified positive changes in physical activity (number of steps) and participation (expansion of life-space) in addition to improvements in functional impairments (e.g., motor paralysis and balance order) in each patient. All three patients were highly satisfied with the TR program. **Discussion:** The results observed in this case series suggest that TR programs are a viable intervention in Japan. TR programs can reduce barriers to continued rehabilitation after discharge and can encourage increased activity and participation.

Key Words: case series; pilot trial; post-stroke; telerehabilitation

INTRODUCTION

Stroke is a global health concern that imposes limitations on stroke survivors' daily activities.[1] Individuals who have experienced a stroke present with motor, sensory, cognitive, and/or mental deficits that diminish their quality of life (QOL).[2] Recovery rates vary, with some individuals needing prolonged assistance.[3] Therefore, post-stroke rehabilitation is often necessary not only during a patient's hospitalization but also on a continuous basis after discharge. However, to receive continuous rehabilitation, post-stroke patients may face challenges such as transportation expenses, the cost of rehabilitation programs, and a lack of family support.[4]

In recent years, telerehabilitation (TR) has attracted attention as a method for patients to continue their rehabilitation after discharge.[5] TR programs use devices such as smartphones and computers to facilitate therapy without physical contact between the patients and healthcare professionals.[5] This innovative approach allows chronically ill patients (especially stroke survivors) to undergo rehabilitation at home, bridging the gap for patients who require sustained intervention.[6] It has been demonstrated that stroke survivors who participated in TR showed similar levels of improvements in physical function, performance of activities of daily living (ADLs), and QOL when compared with patients who underwent conventional face-to-face rehabilitation.[7] In another study, the majority of stroke survivors expressed high satisfaction with TR.[8] Therefore, TR appears to be able to

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Table 1. Patient characteristics

Patient	Sex	Age (years)	Lesion side	Time from onset to enrolment (months)	Diagnosis
P1	Male	50	Left	72	Cerebral hemorrhage
P2	Female	56	Right	48	Cerebral hemorrhage
P3	Male	55	Right	12	Cerebral hemorrhage

serve as an alternative intervention for people who are unable to participate in face-to-face rehabilitation. The further development of TR programs as an intervention is necessary to maximize functional recovery and maintenance in stroke survivors after hospital discharge.[9]

Although the effectiveness of TR for stroke survivors has been established, there are few precedents for stroke-specific TR in Japan.[10] As one of the few precedents, Kato et al.[11] evaluated the effectiveness of TR for stroke patients, but they applied a special technique based on virtual reality (VR) technology, which may not be versatile. In fact, they pointed out the following limitations: the operation of a personal computer with the VR system is difficult, and the VR system cannot be applied to some patients.[11] The cost to implement the VR system may also be a concern. In response to this situation and referring to reports from other countries, we designed a simple TR program for stroke survivors in Japan that does not use any special technology; rather, it merely functions through a web conferencing system. Our TR program could promote important elements of rehabilitation, such as the interactions between therapists and patients.[12] In the present pilot study, we examined the clinical courses of three stroke survivors who participated in the new TR program.

Table 2. Changes in patients' clinical data

Assessment	Pre-intervention	Post-intervention
P1		
SIAS–LE (0–25)	8	11
BBS (0–56)	39	50
FAC (0–5)	5	5
mGES (10–100)	44	61
LSA (0–120)	92	102
Steps	13,062	13,038
P2		
SIAS–LE (0–25)	13	13
BBS (0–56)	54	56
FAC (0–5)	5	5
mGES (10–100)	96	100
LSA (0–120)	90	120
Steps	6884	10,085
P3		
SIAS–LE (0–25)	6	6
BBS (0–56)	43	46
FAC (0–5)	4	5
mGES (10–100)	53	53
LSA (0–120)	62.5	63
Steps	2310	4519

Steps given as average steps per day.

CASES

This case series study was conducted in cooperation with COPAIN Inc. (Tokyo, Japan), which provides TR services. Five stroke survivors were recruited through Internet advertisements posted from April 1 to April 31, 2023. The following participation criteria were applied: individuals (1) diagnosed with a past stroke (cerebral hemorrhage or cerebral infarction) and having hemiplegia, (2) without severe higher brain dysfunction or cognitive impairment, (3) with the necessary online environment and knowledge/skills related to the Internet for participating in TR, and (4) without severe orthopedic or cardiovascular disorders that significantly affect ADLs. Two of the five stroke survivors had missing data and were excluded from the study.

We explained the study in advance to the patients orally and in writing and obtained their written consent. All procedures were approved by the ethics committee of Musashigaoka Hospital of Tanakakai Medical Corporation (2022-7) and were conducted in accordance with the tenets of the Declaration of Helsinki.

Patient 1 (P1) was a 50-year-old right-handed man who presented with severe paralysis of the right upper and lower extremities caused by a left cerebral hemorrhage that had occurred approximately 6 years ago. Two years after the onset of his stroke, he engaged in continuous rehabilitation at a rehabilitation hospital and at care facilities. At the time of this study, he had successfully returned to work. He hoped for further improvement in his upper-limb function and to enhance his gait performance through TR (**Tables 1, 2**).

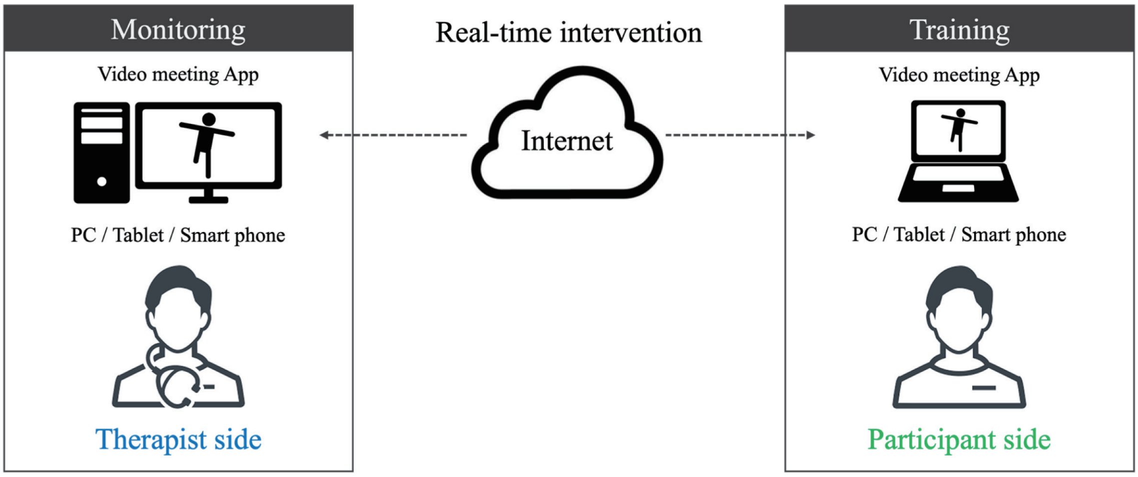

Fig. 1. Overall configuration of the telerehabilitation program.

Patient 2 (P2) was a 56-year-old right-handed woman who presented with severe paralysis of the left upper and lower extremities caused by a right cerebral hemorrhage that had occurred approximately 4 years earlier. For 6 months after the onset, she continuously engaged in rehabilitation at a rehabilitation hospital. At the time of this study, she had successfully returned to society. P2 hoped for further improvement in her upper-limb function and enhancement of her gait performance through TR (**Tables 1, 2**).

Patient 3 (P3) was a 55-year-old right-handed man who presented with severe paralysis of the left upper and lower extremities caused by a right cerebral hemorrhage that he had experienced approximately 1 year earlier. For 6 months after the onset of his stroke, he engaged in continuous rehabilitation at a rehabilitation hospital, and, following discharge, he participated in a weekly in-home rehabilitation program. At the time of the study, he had successfully returned to work. P3 hoped for further improvement in his upper-limb function and enhancement of his gait performance through TR (**Tables 1, 2**).

The TR program

All TR sessions were conducted in an independent space through real-time desktop videoconferencing using Zoom (Zoom Video Communications, Denver, CO, USA) as reported by Lee et al.[13] Two-way audiovisual communication enabled interactions between the parties, allowing the physical therapist to guide the patient (**Fig. 1**). Desks and TV monitors with video cameras were installed in front of the space; this enabled the physical therapist to observe the patient and provide real-time feedback and modification as required.

First, an experienced rehabilitation physician and a physical therapist interviewed the patient in an initial 60-min session. Overall, the session was patient-driven, focusing on his or her current and prior medical history, rehabilitation status, and concerns or goals in life. The session typically included conversations with the following aims: (1) to understand the patient's pathological condition and disability caused by cerebrovascular disease, and (2) to elicit the patient's interest in goal-setting and behavioral change. As the patient's goals were set, a rehabilitation program was developed accordingly.

The rehabilitation programs of the three patients were designed by physical therapists after considering the severity of each patient's performance impairments. The programs included structured exercises with varying degrees of difficulty and varying numbers of exercise sets and repetitions (**Table 3**). The programs were designed based on the TR guidelines from other countries.[14,15] The exercises were also provided to the patients as edited videos to help the patients adopt the exercises as a habit and to engage in behavioral changes (**Fig. 2**).

After the individual interview session, each patient participated in 30-min TR sessions with the physical therapist once every 2 weeks for 6 months. As the primary objective of the TR sessions, the physical therapist monitored the patient's implementation of the TR program and provided direct feedback in real time to allow the patient to adjust exercise load and re-set goals as needed. A caregiver participated in the TR sessions with the patients as necessary and monitored the occurrence of any adverse events, such as falls.

Table 3. Details of telerehabilitation programs

Patient	Objective	Exercises
P1	Acquisition of upper-limb function for work Improved walking performance	Upper-limb exercises: Wrist extension stretch Elbow extension exercise Finger extension exercise Lower-limb exercises: Hip extension stretch Ankle dorsiflexion stretch Ankle dorsiflexion exercise Functional activity: Task-specific training (controlling product) Walking
P2	Improved performance in stair climbing Control of bowl with paralyzed hand at mealtime	Upper-limb exercises: Wrist extension stretch Finger coordination training Lower-limb exercises: Ankle dorsiflexion stretch One-leg squat exercise Functional activities: Task-specific training (controlling bowl) Walking Stepping stairs
P3	Acquisition of upper-limb function for work Improved walking performance	Upper-limb exercises: Wrist extension stretch Finger flexion exercise Finger extension exercise Lower-limb exercises: Ankle dorsiflexion exercise One-leg squat exercise Stepping exercise Functional activities: Walking

During the intervention period, the patients were required to report their daily progress to the physical therapist via a messenger application (LINE; LY Corporation, Tokyo, Japan), especially regarding their implementation of the rehabilitation program. Communication through the messenger app also allowed each patient to consult with a physical therapist about changes in their physical condition or emerging physical problems.

Outcome Measures

All data were collected by a single trained physical therapist. The outcome measures were scores on the Stroke Impairment Assessment Set—Lower Extremity (SIAS-LE),[16] the Berg Balance Scale (BBS),[17] Functional Ambulation Categories (FAC),[18] the Modified Gait Efficacy Scale (mGES),[19] and the Life-Space Assessment (LSA)[20] as measures of change from before to after the intervention. These outcomes were collected remotely from the patients in their homes via webcam. With reference to a previous report on remote neurological evaluation,[21] the therapist conducted the assessment while considering the differences between face-to-face and remote sessions, such as communication, comprehension, and interaction. As an indicator of daily physical activity, each patient used a pedometer to measure their daily number of steps.[22] After completion of the TR intervention, we interviewed each patient to collect their impressions of their participation in the TR program.

Stroke Impairment Assessment Set—Lower Extremity

The SIAS-LE was used to assess the motor dysfunction of the patients' lower limbs associated with cerebrovascular diseases.[16] The SIAS-LE consists of a hip-flexion test, a knee-extension test, and a foot-pat test. Its scores range from

Fig. 2. Screenshot examples of exercise videos provided to participants.

0 to 5, with higher scores indicating better motor function.

Berg Balance Scale

The BBS consists of 14 functional balance tasks that evaluate the participant's balance status in various postures.[17] Each task is scored on a 5-point ordinal scale with possible scores ranging from 0 to 56, with higher scores indicating better balance. The inter-rater and intra-rater reliability of the BBS has been confirmed to be excellent in patients with stroke.

Functional Ambulation Categories

The FAC is a commonly used clinical gait assessment scale with six levels of walking ability.[18] The assessment uses the following scoring system: 0, nonfunctional ambulator; 1, ambulator, dependent on physical assistance—level I; 2, ambulator, dependent on physical assistance—level II; 3, ambulator, dependent on supervision; 4, ambulator, independent, level surfaces only; 5, ambulator, independent. The FAC is a reliable, valid, and responsive assessment tool.

Modified Gait Efficacy Scale

The mGES is a ten-item measure that evaluates the patient's level of confidence in gait during challenging circumstances.[19] The ten mGES items consist of gait on a level surface and on grass, stepping over an obstacle, stepping up and down a curb, ascending and descending stairs (with use of a railing and without), and gait over a long distance. Each item is scored on a 10-point Likert scale with a possible total score range of 10 (lowest confidence) to 100 (complete confidence in all tasks).

Life-Space Assessment

The LSA is a 15-item evaluation of life-space mobility.[20] For each life-space level, the individual being tested is rated according to how many days a week he or she attained that level and whether they needed help from another person or an assistive device. The LSA score reflects the distance moved, the frequency of movement, and level of assistance required for the patient to mobilize. The LSA score can range from 0 to 120, with higher scores indicating greater mobility.

Number of Steps

The daily number of steps of each patient was recorded by a pedometer installed in the patient's smartphone.[22] The patients logged the data each day from the time they woke up to the time they went to bed. The average number of steps per week before and after the intervention were calculated to evaluate the change in the patients' physical activity caused by the TR intervention.

RESULTS

Throughout the 6-month intervention, no patients had adverse events or side effects of any kind (e.g., accidents, falls, and musculoskeletal damage). All patients used the video conference tool and messenger application without problems, and there was no complaint or issue regarding their use. As shown in **Table 2**, P1 recovered some strength in his right lower extremity (SIAS-LE score pre-intervention, 8; post-intervention, 11) and showed improved balance performance [BBS score pre-intervention, 39; post-intervention, 50; minimal clinically important difference (MCID), 5.5][23] over the 6-month intervention. P1 also achieved improvements in gait

Table 4. Qualitative reports from patients

Participant	Participant statements
P1	"I was anxious before I participated in this program, but I was able to continue self-exercise." "I realized that after 3 months into the program, exercise had become a habit." "I felt that daily reporting in the messenger application was important to make exercise a habit."
P2	"Through my participation in TR, I noticed an improvement in my physical function." "TR was very convenient because I did not have to go out to receive rehabilitation."
P3	"Self-exercise management through the messenger application was useful in making exercise a habit." "Setting goals increased my motivation for self-exercise." "I felt that TR was an important service because there were no rehabilitation facilities near my house."

efficacy (mGES score pre-intervention, 44; post-intervention, 61; MCID, 7.38)[24] and life-space mobility (LSA score pre-intervention, 92; post-intervention, 102; MCID, 10).[25]

For P2, the motor paralysis of her lower extremities remained unchanged throughout the 6-month intervention (SIAS-LE pre-intervention, 13; post-intervention, 13), as did her balance performance (BBS score pre-intervention, 54; post-intervention, 56; MCID, 5.5).[23] She showed slight improvement in her gait efficacy (mGES score pre-intervention, 96; post-intervention, 100; MCID, 7.38),[24] but her life-space mobility (LSA score pre-intervention, 90; post-intervention, 120; MCID, 10)[25] showed improvement above the MCID. Her number of steps increased by about 3000 steps/week (from 6883 to 10,085 steps/day) (**Table 2**).

For P3, the motor paralysis of his lower extremities (SIAS-LE pre-intervention, 6; post-intervention, 6) and balance performance (BBS score pre-intervention, 43; post-intervention, 46; MCID, 5.5)[23] were unchanged, but his gait performance (FAC score pre-intervention, 4; post-intervention, 5) improved during the 6-month intervention. His number of steps increased by about 2000 steps/week (from 2310 to 4518 steps/week) (**Table 2**).

In post-intervention interviews, the patients were generally satisfied with the results of the TR program and reported no difficulties in implementation. In particular, the patients reported that the program was effective in improving their physical function and motivating them to adopt exercise as a habit (**Table 4**). The rates of compliance for the exercise program were 93.4% for P1, 90.5% for P2, and 93.2% for P3.

DISCUSSION

We devised a TR program based on reports of TR in other countries and adapted it for use in a trial with stroke survivors living in their communities. After the intervention, the indicators of physical function, activity (number of steps), and participation (life-space mobility) showed improvements, with variation between the patients. In general, the patients showed a high level of satisfaction in terms of their improved physical function and their motivation to exercise as a habit. The results of this case series confirmed the feasibility and usefulness of implementing a simple TR program using only a web conferencing system.

In terms of improvements in physical function, there was significant variation among the patients. P1 showed improvement on the SIAS-LE, whereas the respective scores for P2 and P3 remained unchanged after the intervention. For the BBS, the improvement of P1 (from 39 to 50) was regarded as clinically meaningful, based on an MCID of 5.5 for patients with chronic stroke.[23]

Currently, there is a wide variety of TR methodologies, and, among them, the use of VR systems have attracted increased attention in recent years.[7] Although the application of VR technology is useful for improving the performance of patients, the technology is neither versatile nor inexpensive.[11] Therefore, we focused our study on a simple TR program that uses only a web conferencing system. Our TR program was characterized by real-time interactions between therapists and patients. This allowed precise adjustment of exercise difficulty based on the functional impairment and disability of each participant. In addition, considering that the exercises were designed to be performed daily, a greater amount of practice was expected to result in greater effectiveness of practice. In fact, a study based on a design that is similar to the present study (real-time interaction between therapists and participants) reported that participation in a TR program improved the balance performance in individuals with chronic stroke.[26] Even without special techniques, this highly individualized program based on real-time interaction between therapists and patients was considered to contribute to patients' improved physical functions.

As an effect of the TR program, P1 developed an exercise habit, suggesting that the adjustability of the exercises and the amount of practice contributed to the improvement of his physical function. However, improvement of physical function was observed only in P1 and was not observed in P2 or P3. The reason for this outcome is unclear, although it may have been related to the ages of the patients; P1 was the youngest of the three. The courses of these patients suggest that there are patients for whom TR intervention is more effective (responders), and further research is necessary to identify the factors that contribute to improvements of physical function.

Similar to physical function, improvements in activity and participation varied between patients. Notably, change in the LSA score exceeded the MCID[25] in P1 and P2, and the number of steps improved markedly in P2 and P3. These changes could be interpreted as our TR program facilitating an expansion of the living space and an increase in the amount of physical activity. In this respect, Chumbler et al.[27] reported that compared to usual care, TR promoted life tasks such as ADLs and social roles in the home. They also suggested that the mechanism underlying this improvement involves the contents of the TR intervention, which focuses on physical skills and activities inside the home.[27] In our TR program, goals were selected in accordance with the patient's lives and goal-oriented exercises were devised. Such interventions should contribute to improvements in not only patients' physical function but also in their levels of activity and participation. Although P1 showed no improvement in the number of steps, he was taking about 10,000 steps/day before the intervention, which was far more than the other patients. Therefore, it is possible that P1 was already performing at a high step rate. Although the LSA score of P3 did not improve with TR, he had poorer gait performance (FAC 4) than the other patients (FAC 5). When P3 went outside his home, he needed to be accompanied by his wife, and we suspect that such restrictions prevented a significant improvement in his LSA score.

In the post-intervention interviews, all three patients indicated that they were highly satisfied with the TR program. Other studies revealed that home-based exercise therapy significantly improved participant QOL and satisfaction during the study period,[13,28] and the intervention heightened the participants' interest and intention to participate in therapy in the future.[13,28] In the present patient series, there was no report of adverse events, such as safety incidents, falls, or musculoskeletal injuries, suggesting that our TR program is a beneficial, safe intervention for stroke survivors and provides high participant satisfaction. Remotely facilitated rehabilitation using web conferencing systems can be recommended for stroke survivors who face barriers to rehabilitation and during infectious disease epidemics.

CONCLUSION

This pilot study demonstrates that TR not only has the potential to eliminate barriers to rehabilitation, but also can improve physical function, activity, and participation of stroke survivors. In many respects, this approach could be used as an alternative to conventional outpatient rehabilitation after discharge. However, the TR program described herein can only be adopted for use in stroke patients who do not have cognitive or higher brain dysfunction and who have at least a minimum level of Internet literacy to make use of our tools. Indeed, another study pointed to the limitations of adaptation for people with cognitive impairments.[7] Nevertheless, compared to TR programs using specialized techniques such as VR, our program is expected to be more versatile and easier to implement in clinical practice because of its simplicity. In future, we plan to improve the accuracy and expand the range of indications for our TR program and accumulate more cases to further test the effectiveness of TR in Japan.

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CONFLICTS OF INTEREST

RF and ST hold consultancy agreements with COPAIN Inc. TT declares no conflict of interest.

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