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Complete List of Authors:	Li, Cabbee T. L.; The Hong Kong Polytechnic University, Rehabilitation Sciences Hung, Goris K. N.; The Hong Kong Polytechnic University, Rehabilitation Sciences Fong, Kenneth N. K.; The Hong Kong Polytechnic University, Rehabilitation Sciences Cruz Gonzalez, Pablo; The Hong Kong Polytechnic University, Rehabilitation Sciences Wah, S. H.; Haven of Hope Hospital, Geriatric Day Hospital Tsang, Hector W.H.; The Hong Kong Polytechnic University, Rehabilitation Sciences
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Title:

The Effects of a Home-Based Occupational Therapy Telerehabilitation via Smartphone for Outpatients after Hip Fracture Surgery: A Feasibility Randomized Controlled Study

Cabbee T. L. LI[1,2]

Goris K. N. HUNG[1]

*Kenneth N. K. FONG[1]

Pablo CRUZ GONZALEZ[1]

S. H. WAH[2]

Hector W. H. TSANG[1]

[1]Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong

[2]Geriatric Day Hospital, Haven of Hope Hospital, Hong Kong

*Correspondence:

Kenneth N. K. Fong, Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Kowloon, Hong Kong. Fax: +852 23308656; Email: rsnkfong@polyu.edu.hk

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Abstract

Objective: To investigate the effects of a home-based occupational therapy telerehabilitation (TR) via smartphone in enhancing functional and motor performance and fall efficacy for outpatients receiving day hospital rehabilitation after hip fracture surgery in Hong Kong.

Methods: This was a feasibility randomized controlled trial with two groups, an experimental group and a comparison group, and a sample of 31 older adults attending a geriatric day hospital who had undergone hip fracture surgery within 12 weeks of diagnosis. Patients were assessed at baseline, immediately after a 3-week intervention, and at 3-week postintervention follow-up for motor performance, activities of daily living (ADL) functioning, and fall efficacy. The experimental group received a home program using the Caspar Health e-system and a mobile app for smartphones, while the comparison group received paper-and-pencil instructions for the home program on a weekly basis for 3 weeks.

Results: Compared with the comparison group, significant improvements in fall efficacy and instrumental ADL performance at postintervention and follow-up were found in the experimental group. However, in the comparison group, inadequate social support was a factor contributing to better muscle strength testing in both the affected and nonaffected legs. There were no significant differences between the two groups in regard to the other variables.

Conclusion: This study supports the potential use of TR via smartphone as an alternative home program for use in occupational therapy practice with older adults after hip fracture surgery.

(word count: 222)

Keywords: Telerehabilitation, home-based training, older adults, hip fracture, occupational therapy

Introduction

There is an increasing prevalence of geriatric hip fracture because of the ageing population worldwide. Ninety-eight percent of geriatric hip fractures are managed in hospital with or without an operation.[1] However, less than half of geriatric hip fracture patients regain their prefracture physical and functional ability, which encompasses their mobility and activities of daily living (ADL) performance, thus potentially increasing their risk of falling.[2] The overall 30-day and 1-year postoperative mortality rates after hip fracture are 3.01% and 18.56%, respectively.[3] A longer period of recovery, maybe taking up to one year after inpatient discharge, might be expected after hip fracture.[4] Moreover, rates of readmission to hospital are high after hip fracture, and falls are the single most common reason for readmission, with patients with lower levels of mobility being twice as likely to be readmitted than those who were able to walk independently with or without a walking stick prior to their hip fracture.[5]

Telerehabilitation (TR) refers to the use of information and communication technology to provide rehabilitation services at a distance.[6-8] TR is not a new concept: arguably, it began in the late 1990s with the development of internet communication. However, in the digital and mobile technology era, it has been transformed since the introduction of smartphones to the commercial market in the mid to late 2000s. With mobile technology, occupational therapists are well positioned to facilitate timely, safe, and successful hospital discharge for patients following hip fracture[5] and to affect patients' health outcomes after hospital discharge by using their expertise and understanding of how a person interacts with their environment to provide guidance on functions which impact on a patient's health and wellbeing as they transition home.[9] In 2014, the World Federation of Occupational Therapists acknowledged that TR is an appropriate service delivery model for occupational therapy services.[10] A recent review showed that occupational therapy via TR offers user-friendly treatment for patients at home and that patients and caregivers are in general satisfied with the use of TR in occupational therapy

services.[11] Recent reviews found that TR has similar clinical outcomes when compared to face-to-face rehabilitation services in various pathologies and impairments.[7,12-19] Moderate to strong evidence on motor recovery in lower limbs during postoperative recovery after the application of TR has been found.[20-21]

The penetration of smartphones in Hong Kong is high, with around 86% of people aged 10 and above owning a smartphone.[22] A recent systematic review showed that studies on the effectiveness of TR in occupational therapy, particularly the use of smartphone technology, are very limited.[11] Moreover, it is not yet known whether smartphone technology is useful to the delivery of home-based TR programs for patients after hip fracture.

Therefore, the objective of this study was to investigate the effects of a home-based OT program via TR using smartphone technology as compared to paper-and-pencil instructions for outpatients receiving day hospital rehabilitation after hip fracture surgery in Hong Kong. We hypothesized that using TR for a home program is more effective in enhancing older adults' functional and motor performance, as well as their fall efficacy, than a home program via paper-and-pencil instructions during day hospital rehabilitation.

Methods

Participants

Patients were recruited from a geriatric day hospital in a convalescent hospital. The inclusion criteria were as follows: (1) primary diagnosis of hip fracture; (2) post-hip fracture surgery within 12 weeks of diagnosis; (3) aged 60 years old or above; (4) medically stable; (5) an Abbreviated Mental Test (AMT) score of 6 or above;[23] and (6) having at least one functional limitation in the basic ADL assessments. Patients were excluded if (1) their hip fracture was the result of malignancy; (2) there was a risk of falls due to postural hypotension; (2) they or their caregivers did not understand Cantonese, English, or Mandarin instructions; (3) they did

not use a smartphone; or (4) they were unable to read the instructions on the screen of the smartphone because of visual difficulty.

Baseline demographic characteristics, including age, gender, and level of education, and information with regard to site of injury, type and side of operation, length of hospital stay, visual functioning, ADL performance, number of drugs taken, activity levels, mobility status, use of mobility aid, and social supports were obtained from hospital medical notes. The study was approved by the Human Ethics Committee of the Hong Kong Polytechnic University for research involving human subjects (Ref: HSEARS20180523002) and the Ethics Committee of Kowloon Central/Kowloon East Cluster in the Hospital Authority (Ref: KC/KE-18-0075/ER-4). The clinical trial registration number (URL: http://www.clinicaltrials.gov) is NCT04259294.

Procedures

The purpose and procedures of the study were clearly explained to all patients before commencement. Once informed written consent to participate in the study was obtained, patients were randomly allocated by means of computer randomized numbers to either the experimental group receiving TR or the comparison group receiving paper instructions. The contents of the home program in both groups were tailor-made according to the needs of each case by occupational therapists who were not blinded to the treatment as it was not possible to blind patients from the treatment. Activities of the home program were reviewed individually by occupational therapists twice a week while they were attending rehabilitation sessions at the day hospital. Outcome measures were evaluated at baseline, immediately after a 3-week intervention, and at 3-week postintervention follow-up. All assessments were administered by blind assessors.

Intervention

TR was delivered through the Caspar Health e-system[a] (CASPAR Health, Berlin, Germany), a German-design internet system for desktop and a mobile app for both iOS and Android smartphones which enables patients to directly interact with and seek advice from the hospital or to do exercise anywhere according to the therapists' treatment plan through digital communication. The system we used was adapted by the company to provide traditional Chinese characters with Cantonese dialect speech for Chinese people in Hong Kong (https://caspar-health.com/zh-Hant/). Figure 1 shows a schematic diagram of the home-based occupational therapy TR program in the Caspar Health e-system: (1) Therapists set a tailor-made TR program for each patient through the e-system calendar, and data, such as exercise videos and frequency, are transferred to the patient's mobile phone or tablet through the Caspar Health App; (2) the patient performs the home-based training using the videos, pictures, and written and verbal instructions shown on the app, with or without assistance from their caregivers; (3) after practice, the patient uploads their training video or verbal feedback to the therapists so that the therapists can update the home program according to the patient's progress. The Caspar Health e-system also allows therapists to review patients' attendance records and communicate with them if needed. All data are stored exclusively on a server with high-level encryption and transmitted over a secure connection.

In this study, home-based treatment videos targeted for postoperative hip fracture rehabilitation were tailor-made and filmed in advance by the investigation team. The video contents were modified with reference to a standardized LiFE home training program in which movements specifically prescribed to improve balance or increase strength are embedded within everyday activities.[24-25] Examples include weight shifting with holding the furniture to simulate the functional mobility, repeat crossover the curb to simulate getting into and out of the bathroom, sit to stand from the chair, forward reaching with holding the armrest in sitting

position to simulate dressing, etc. A setup session to educate patients and/or caregivers in the experimental group on how to use the apps was provided in the first session in the hospital.

Patients in both the experimental and comparison groups attended 1.5-hour conventional occupational therapy training sessions at the day hospital twice a week for 3 weeks. They also received physiotherapy, nursing care, and consultations with a medical doctor in the day hospital. The experimental group received a home-based treatment program through mobile apps, while the control group received their program through written home program sheets. The training contents were equivalent, including trunk and lower limb strengthening and stretching, coordination, balance, and functional exercises that were related to the patients' daily living activities in their home environments. The frequency and duration of a patient's home program were jointly determined and agreed by the therapist and the patient. For the experimental group, the videos of the home program were sent to the app on patients' smartphones by the therapist. An educational session on the use of the mobile app was provided for the experimental group during the initial intake session. Patients performed the exercises while watching the videos on the app. After each exercise was completed, patients' performance feedback was captured by their smartphone and sent back to the case therapist each time through the app, while patients in the control group recorded their performance on a log sheet provided by the therapists. The feedback included whether they experienced any pain during the home program and their subjective feelings after performing the exercises. The case therapist followed up on the patients' feedback and reviewed their progress on the home program through the e-system on the computer or the log sheet twice a week, and revised the training if needed when they met the patients face-to-face in the hospital. A phone stand to support the smartphone was given to the patients in the experimental group to ensure safety and clarity while they simultaneously watched the videos and performed the home program.

Outcome Measures

Primary outcomes were measured in terms of motor performance, and the secondary outcomes were functional performance and fall efficacy.

Primary outcomes. Four motor performance scales were used to assess pain perception, quadricep strength, balance, and walking speed.

The timed up and go test (TUG) was used to measure fall risk and progress in walking speed. The time taken for a person to rise from a chair, walk 3 meters, turn around, walk back to the chair, and sit down was measured.[26] The Functional Reach Test (FR) is a screening test to measure balance and can be used to assess fall risk in older adults. It measures the difference between arm's length and maximal forward reach.[27-28] Muscle strength testing was evaluated by using a force gauge to measure the strength of the quadriceps of the affected leg and the non-affected leg as both are important to the quality in walking and sit-to-stand activities.[28] The Pain Visual Analogue Scale (VAS) is a single-item measure of pain intensity. It consists of a 100mm horizontal line anchored with two opposite labels (i.e., labelled at the left end as 'no pain' (0mm) and at the right end as 'very severe pain' (100mm)).[29]

Secondary outcomes. The Hong Kong Chinese version of the Modified Barthel Index (MBI) was used to measure the degree of independence in ADL performance.[30] The Hong Kong Chinese version of the Lawton Instrumental Activities of Daily Living (IADL) scale assesses nine domains of function skills (ability to use telephone, shopping, meal preparation, laundry, housekeeping, handyman work, and transportation, medication and money management).[31] Fall efficacy refers to assessing one's own degree of perception of fall risk and one's level of confidence about being able to perform daily activities without fear of falling. The Morse Fall Scale (MFS) was used to predict the likelihood of falls. This scale consists of six variables: history of fall, the presence of a secondary diagnosis, the use of ambulatory aids, the

administration of intravenous therapy, type of gait, and mental status.[32] The Fall Efficacy Scale (FES) is a questionnaire to assess the level of confidence a patient has in their ability to perform ADL without fear of falling.[33-34]

Statistical Analysis

Baseline differences in the demographic characteristics between the two groups were examined using the Mann-Whitney U independent sample test for the continuous variables and chi-square tests for the categorical variables. To compare the outcomes between the two groups at pretest, posttest, and follow-up, repeated measures ANOVA was used to analyze all the primary outcome measures. Any variable with a significance difference in the baselines between the two groups would be used as covariance in the comparison. A further comparison of mean scores was conducted to investigate the alternative hypothesis. Missing data were analyzed on an 'intention-to-treat' basis. The sample size in this study was predicted according to the reference of a study on the significant increase in Quadriceps strength of the affected leg (kgf) in the experimental group using home exercise for patients with hip fracture compared with the control group.[35] By using G-power and assuming one-tailed alternative hypothesis with 99% power, at Type I error of 5% and mild-to-moderate effect size f=0.38, a sample of 54 participants were required to detect significant difference of motor improvement between the experimental and the control groups (GPower Version 3.0.10). Therefore, assuming a 10% dropout rate, a total of 60 participants was needed.

Results

Figure 2 shows the flowchart of the study. Sixty-nine patients were screened, and 40 of them were eligible for this study. Thirty-one patients were successfully recruited between June 2018 and May 2019. We identified several reasons for patients refusing to participate in the study: problems related to the procedures of study (difficulty understanding the consent form

and using the mobile app); fear of overexercising apart from attending the standardized treatment in the day hospital; feeling overwhelmed in adapting to the standardized treatment in the day hospital; feeling fatigued after the study intake; and a feeling of uncertainty about joining the "research." Eventually, 15 patients were allocated to the experimental group and 16 patients were assigned to the control group. All patients completed the training program, and 30 of them attended the follow-up session. One patient in the control group did not attend the follow-up session because of readmission to hospital.

Table 1 shows that there were no significant differences between the two groups in any of the demographics or in regard to AMT scores, length of hospital stay, side of injury, site of injury, type of operation, family relationship, ADL performance, physical activity level, mobility status, and use of mobility aids ($p>0.05$). However, a significant difference between groups in regard to social support was found at the baseline ($p=0.049$). All of the patients in the experimental group lived with a domestic helper or family members, while 25% of the patients in the control group lived alone.

Table 2 shows that there were no significant differences in TUG, FR, pain VAS, MBI, and FES between the two groups at pretest, posttest, and follow-up ($p>0.05$). Significant interaction effects between group and time occasions were found in the muscle strength testing over both the affected side (MTA) ($p=0.025$) and muscle strength testing of the nonaffected side (MTN) ($p=0.015$); the MFS ($p=0.002$); and the Lawton IADL scale ($p=0.010$). Although no significant difference was found in the between-group effect ($p>0.05$), the experimental group showed greater improvement in the mean scores of the MFS and Lawton IADL scale in the posttest (Means – MFS: Exp: -5.4, Control: -0.7; Lawton IADL scale: Exp: +4, Control: +1.15) and follow-up (Means – MFS: Exp: -3, Control: -0.6; Lawton IADL scale: Exp: +2.9, Control: +0.95). The control group had a slightly higher mean score of MTA in the posttest

(Mean - Exp: +2, Control: +2.3) and MTA and MTN in the follow-up (Mean - MTA: Exp: -0.9, Control: +0.6; MTN: Exp: -0.8, Control: +0.6). A decreased mean score on muscle strength in both legs was noted for the experimental group (MTA: -0.9; MTN: -1.2) in the follow-up, while the control group maintained a similar score in the follow-up.

A high adherence rate in terms of completing 90% of the home program was found for both the experimental group (87%) and the control group (86%). Two patients in the experimental group only completed 50% of the home program due to technical problems in using the app in the initial stage of the study. Two patients in the control group did not commit to the majority of the home program due to low motivation and readmission to hospital, respectively.

Discussion

Nowadays, most elderly patients wish to spend their old age in their own home, it will be very important for healthcare providers to support them in their homes using remote technology than they could obtain by visits to hospitals.[36] In this study, we found that patients using TR and the mobile app for the home program showed slightly better improvement in the secondary outcomes (MFS and Lawton IADL scale) than those using the paper-and-pencil instructions. The mobile app in the TR provided videos that showed clear verbal instructions and demonstrations for patients to follow while doing the home program. We expected that patients in the experimental group might have greater confidence and engagement in IADL, such as going outdoors to shop and participating in household chores, and reduce their fall risk in daily life accordingly, as indicated by their improvement in MFS. The reason for this phenomenon might be that more participants in the experimental group had someone with them that could help with fall prevention as well as their interest to engage in other instrumental activities of daily living that someone alone might not be able or willing to do. However, disappointingly,

no significant differences were found in the primary outcomes (TUG and FR) between the two groups. Balance is a complicated ability that demands both sensory and motor components,[37] and thus strengthening and functional training on its own might not have been enough to bring about significant improvement in TUG and FR in the two groups. In addition, patients in both groups were receiving active rehabilitation at the day hospital, and this might possibly explain why no significant difference was found in the patients' subjective perception of fear of falling in the FES. With regard to the pain VAS and the MBI, the baseline score indicated that patients might have reached their optimum score in the scales and that a ceiling effect likely existed on these measurement tools. Surprisingly, it was disappointing to find a greater improvement in quadricep strength in both legs in the comparison group than in the experimental group receiving TR.

Our study has some limitations. The sample size was too small. The number of patients recruited was much less than the predicted sample size due to the high refusal rate of eligible patients within the study period. Some older adults were not eligible as they did not have a smartphone and thus could not be recruited during the randomized group-allocation process. The average number of years of education among the older adults was around 4.8 years, which might have had an impact on their skill in using smartphones and mobile apps. Technical problems arose in carrying out TR in the study: problems occurred with patients using their own mobile phones or tablets—difficulty opening the app; problems receiving a Wi-Fi signal or lacking the high data speed needed to upload the app or video to the Cloud. These problems could not easily be solved by the older adults themselves, and thus on-going technical support from the therapists or caregivers was necessary. Patients also stated that a larger mobile phone with a bigger screen would have been beneficial to them. Moreover, we had not recorded the time taken by the therapists to review the patient videos and prepare/adjust the TR program.

Conclusion

Our study found that an occupational therapy home-based program via TR was better than paper-and-pencil instructions in enhancing fall efficacy and IADL performance, but not walking speed, balance, and quadricep strength, in older adults receiving day hospital rehabilitation services after hip fracture. TR can be applied at home for those who have difficulty in travelling, particularly those who are too frail and tired after prolonged hospitalization and hip surgery, live a long way from the hospital providing day training, or live in remote districts and have difficulty in arranging transportation to hospital for further rehabilitation.

(Words: 3,098)

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Declaration of Conflicting Interests

This research received the grant from Caspar Health Limited. I had full access to all of the data in this study and I take complete responsibility for the integrity of the data and the accuracy of the data analysis

[a]**Equipment**

Caspar Health Limited – The first digital therapy platform (https://www.caspar-health.com/)

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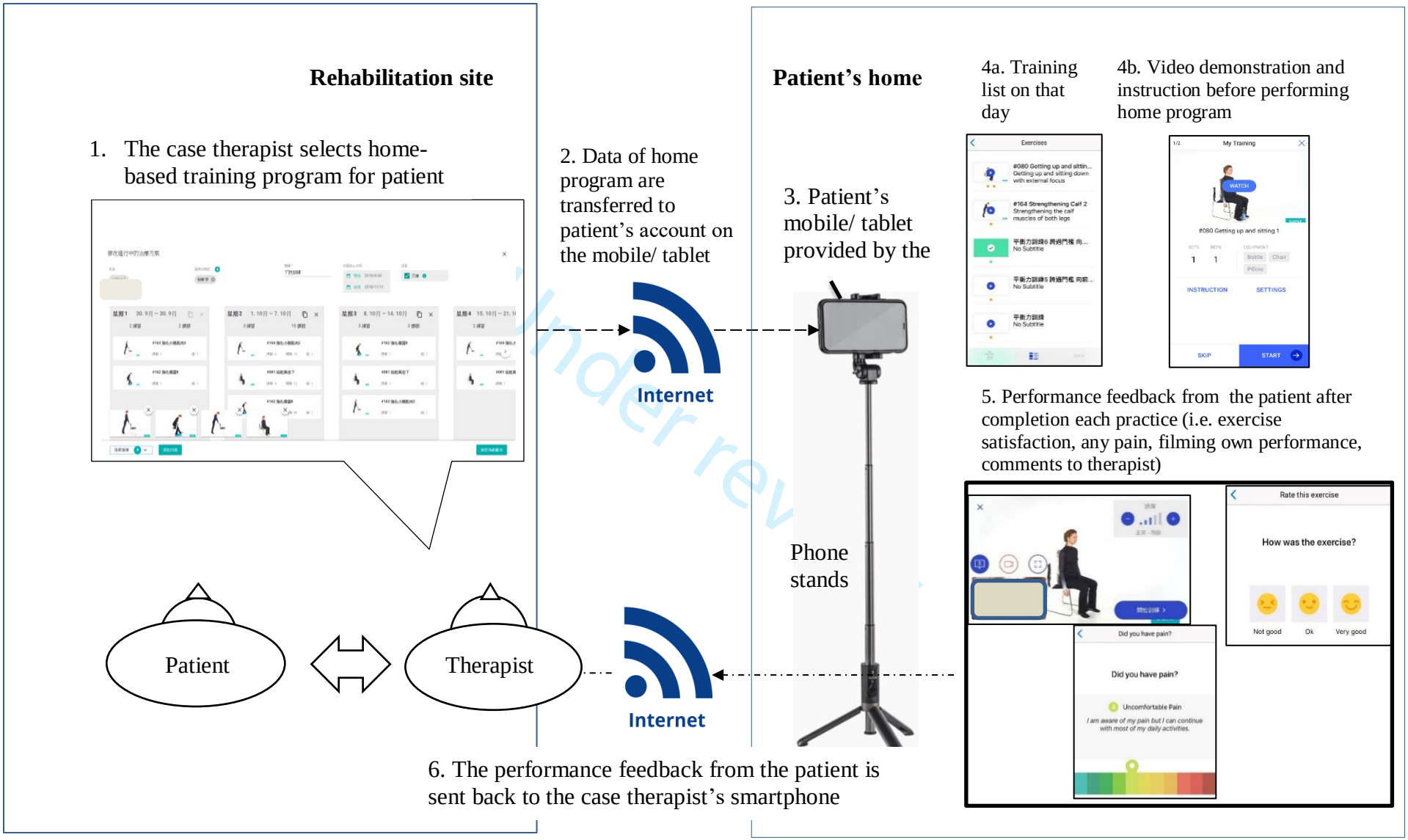

Figure 1. Schematic diagram showing the home-based occupational therapy TR programme in the Caspar e-system.

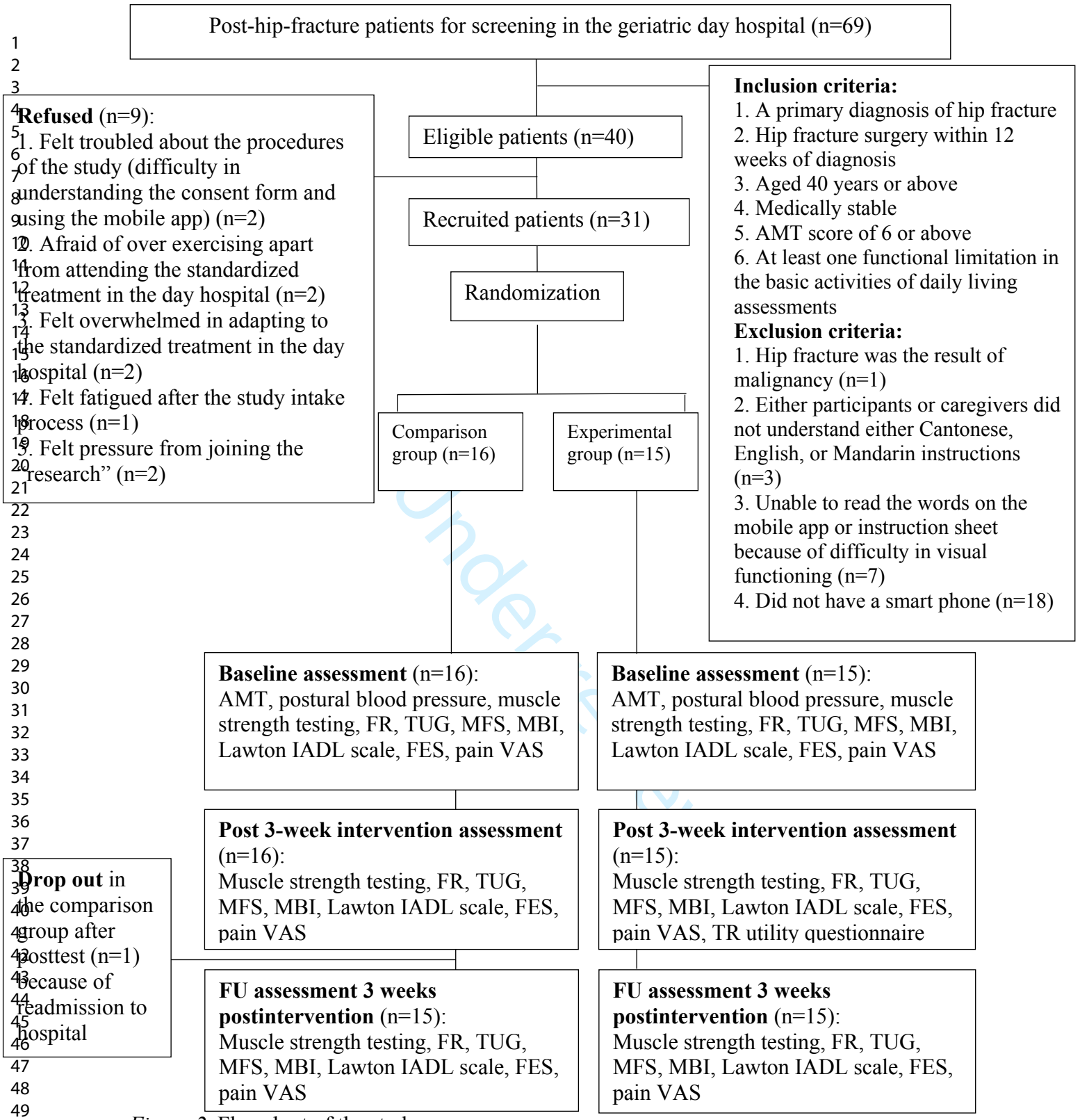

Figure 2. Flowchart of the study.

Note. AMT=Abbreviated Mental Test; TUG=timed up and go test; FR=Functional Reach Test; VAS=Visual Analogue Scale; MFS=Morse Fall Scale; MBI=Chinese version of Modified Barthel Index; FES=Fall Efficacy Scale; IADL= Instrumental Activities of Daily Living; TR=telerehabilitation; FU=follow-up

Table 1
Demographic Characteristics of Patients (n=31)

Variable		Comparison (n=16)	Experimental (n=15)	p¶
Age (years) (Mean, SD)		82.1 (9.7)	76.5 (8.6)	0.097
Education level (years) (Mean, SD)		4.5 (4.6)	4.8 (4.5)	0.840
No. of drugs taken (n) (Mean, SD)		5 (3.4)	7 (3.1)	0.095
Length of hospital stay (days) (Mean, SD)		30.2 (10.6)	37.4 (12.9)	0.099
AMT (Total score) (Mean, SD)		8.8 (1.2)	9 (0.6)	0.619
Gender (n, %)				0.083
	Male	5 (31%)	1 (7%)	
	Female	11 (69%)	14 (93%)	
Side of injury (n, %)				0.320
	Right	7 (44%)	4 (27%	
	Left	9 (56%)	11 (73%)	
Site of injury (n, %)				0.160
	NOF	9 (56%)	11 (73%)	
	TOF	6 (38%)	2 (13%)	
	Hip	0 (0%)	2 (13%)	
	Femur	1 6%)	0 (0%)	
Type of operation (n, %)				0.526
	PFNA	6 (38%)	3 (20%)	
	AMA	4 (26%)	3 (20%)	
	DHS	0 (0%)	1 (7%)	
	Screw fixation	1 (6%)	4 (26%)	
	Im nail	1 (6%)	0 (0%)	
	Bipolar hip arthroplasty	1 (6%)	3 (20%)	
	Hemiarthroplasty	2 (12%)	1 (7%)	
	Unipolar arthroplasty	1 (6%)	0 (0%)	
Social support (n, %)				0.049*
	Live alone	4 (25%)	0 (0%)	
	Live with family and/or domestic helper	12 (75%)	15 (100%)	
Family relationship (n, %)				0.211
	Good	13 (81%)	15 (100%)	
	Fair	2 (13%)	0 (0%)	
	poor	1 (6%)	0 (0%)	
ADL performance (n, %)				0.372
	Independent	12 (75%)	9 (60%)	
	Partially dependent	4 (25%)	6 (40%)	
Physical activity level (n, %)				0.423
	Sedentary	0 (0%)	1 (7%)	
	Moderately active	8 (50%)	9 (60%)	
	Active	8 (50%)	5 (33%)	
Mobility status (n, %)				0.354
	Ambulatory independent	13 (81%)	10 (67%)	
	Ambulatory with assistant	3 (19%)	5 (33%)	
	Chair bound	0 (0%)	0 (0%)	
Use of mobility aid (n, %)				0.876
	Unaided	1 (6%)	2 (14%)	
	Stick	3 (18%)	3 (21%)	
	Quad	2 (12%)	1 (7%)	
	Frame	10 (64%)	9 (58%)	
	Rollator	0 (0%)	0 (0%)	
Postural hypotension (n, %)				0.999
	Yes	0 (0%)	0 (0%)	
	No	16 (100%)	15 (100%)	
Visual function (n, %)				0.157
	Good	14 (88%)	15 (100%)	
	Blurred	2 (12%)	0 (0%)	

Note. SD=standard deviation; n=number; NOF=neck of femur; TOF=trochanter of femur; PFNA=proximal femoral nail autorotation; AMA=Austin Moore arthroplasty; DHS=dynamic hip screw; Im nail=intramedullary nail; avg.=average; SD=standard deviation; ¶Mann-Whitney U independent sample test was used for continuous data and Pearson's Chi-Square tests (2-sided) were used for categorical data; *p≤0.05

Table 2

Comparison of Outcome Measures between and Within Groups (Experimental Group=15, Comparison Group=16)

Outcome measure		Mean ±SD			Level of significance (p)		
		Pretest	Posttest	Follow-up	Multivariate	Univariate	
						Within-group	Between-group
TUG	Experimental	39.7 ±26	33.8 ±19.6	29.9 ±22.6	0.420	0.701	0.467
	Comparison	45.2 ±15.8	39.5 ±18.0	31.8 ±16.8			
FR	Experimental	4.1 ±3.9	5.2 ±3.5	5.8 ±2.7	0.053	0.041*	0.751
	Comparison	3.7 ±3.0	5.5 ±3.4	5.3 ±2.6			
Muscle strength testing—affected side Force gauge (kgf)	Experimental	4.3 ± 1.7	6.3 ±1.8	5.4 ±1.7	0.025*	0.017*	0.666
	Comparison	3.8 ±2.1	6.1 ±2.9	6.7 ±2.5			
Muscle strength testing—non affected side Force gauge (kgf)	Experimental	7.0 ± 2.6	7.4 ±1.8	6.2 ±1.5	0.015*	0.052	0.510
	Comparison	6.8 ±2.9	7.0 ±2.3	7.6 ±2.7			
Pain VAS	Experimental	3.47 ±2.6	1.8 ±1.9	1.8 ±2.1	0.339	0.264	0.550
	Comparison	2.4 ±2.6	1.5 ±1.8	1.9 ±2.7			
MFS	Experimental	63.7 ±7.7	58.3 ±8.8	55.3 ±9.2	0.002**	0.000**	0.563
	Comparison	61.6 ±9.4	60.9 ±9.5	60.3 ±9.6			
MBI	Experimental	82.8 ±8.4	87.8 ±8.2	90.9 ±8.9	0.213	0.161	0.338
	Comparison	81.9 ±6.4	84.4 ±6.8	87.3 ±8.2			
FES	Experimental	56.3 ±17.8	64.9 ±19.3	74.6 ±22.9	0.135	0.279	0.900
	Comparison	55.9 ±17.0	68.0 ±15.6	69.5 ±19.4			
IADL	Experimental	8.9 ±3.4	12.9 ±5.2	15.8 ±6.9	0.010**	0.002**	0.626
	Comparison	10.6 ±4.9	11.75 ±4.9	12.7 ±5.1			

Note. SD=standard deviation; kgf=kilogram force; TUG=Timed Up and Go Test; FR=Functional Reach Test; VAS=Visual Analogue Scale; MFS=Morse Fall Scale; MBI=Modified Barthel Index; FES=Fall Efficacy Scale; IADL=Lawton Instrumental Activities of Daily Living scale; *p≤0.05; **p≤0.01