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Research Paper

Recovery after ischemic stroke: Effects of FuekFone home-based program on upper limb and cognitive function

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Objectives: This study aimed to explore the effects of the "FuekFone (F.F.) home-based program" on the upper limb and cognitive function of ischemic stroke patients after discharge.
Methods: A single group pre-and post-test design was conducted. A total of 40 patients with recovery after ischemic stroke were recruited from two university hospitals in Thailand. The study was conducted between June 2022 and January 2023. Participants underwent a six-week "F.F. home-based program," which combined an upper limb and cognitive function rehabilitation device with Android games, including stationary barrel, adventure walk, adventure stroll, sliding barrel, sauce squeeze, and cut objects. Each game has different difficulty levels. Patients can perform corresponding exercises through the games according to their conditions under the guidance of medical staff. The patients played for 24 min per time, 4 min each game, three days a week. The second week, let the patients play games for 30 min per time, 5 min each game, 3 days a week. Then, in the 3–6 weeks, let the patients play games for 1 h per time, 10 min each game, 5 days a week. At the pre-and post-intervention, the Thai version of the National Institutes of Health Stroke Scale (NIHSS), the Motor Assessment Scale, and the Montreal Cognitive Assessment (MoCA score) were administered to patients at discharge and at 2, 4, and 6 weeksafter discharge, and the results were compared.
Results: All participants completed this program. Participants had statistically improved upper limb function (upper arm function score, hand movements score, advanced hand activities score, total Motor Assessment Scale score) and MoCA score at 2, 4, and 6 weeks after discharge ($P < 0.001$). In the comparison of upper limb function and cognitive function at each of the study times, we found statistically improved upper limb function (upper arm function score, hand movements score, advanced hand activities score, total Motor Assessment Scale score) and MoCA score at 4, and 6 weeks after discharge when compared to after discharge and 2 weeks after discharge, respectively ($P < 0.05$).
Conclusions: Continuing care of patients post-stroke after discharge from hospital, such as F.F. home-based program should be applied at home to enhance upper limb and cognitive function.

What is known?

- Stroke patients require continuous rehabilitation after a stroke, such as motor and cognitive function, particularly the transition phase from hospital to home, to promote recovery and prevent disability.
- There is evidence of the integration of technology to promote stroke rehabilitation, such as upper limb and cognitive rehabilitation, particularly a home rehabilitation program.

What is new?

- "FuekFone (F.F.) home-based program" tends to improve the motor and cognitive function.

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- This program should be used to rehabilitate the patient before discharge from the hospital to home and during the rehabilitation period.

1. Introduction

A frequently encountered neurological disease with increasing prevalence each year is stroke. A report by the WHO [1] stated that the global incidence of stroke is estimated that one in four people will have a stroke in their lifetime. Stroke is a worldwide problem, this burden is particularly catastrophic in Asia, where mortality is higher than in Europe and North America, and resources are limited. In Thailand, a five-year retrospective data report (from 2013 to 2017) by the Ministry of Public Health, Department of Disease Control, Strategy and Planning Division (2020) [2] revealed that the mortality toll of stroke patients had increased from 237,039 to 304,807. Ischemic stroke is more frequently encountered than hemorrhagic stroke by three-fourths of all stroke cases [1]. In Thailand, ischemic stroke is found in 70%-85% of all cases, and although hemorrhagic stroke is more severe, its rate is lower at 15%-30% [2].

Although the mortality toll has been increasing, a large number of stroke patients survive after the onset of the disease. However, survivors still face some severe sequelaes, such as disability. The WHO [3] reported there were 15 million stroke patients who faced disability problems. Furthermore, in Thailand, a report by the Siriraj Stroke Center stated that disability was present in as many as 70% of patients after discharge [4]. The top five commonly encountered symptoms include limb weakness, balance problems, stroke recurrences, speech problems, and joint stiffness, at 52.2%, 35%, 23.2%, 14.8%, and 7.9%, respectively [5]. Additionally, Khalid et al. [6] found that 70% of patients suffered post-stroke from at least one complication, leading to impairments in movements and activities of daily living [7]. Disabled stroke survivors are less able to perform activities of daily living, become dependent, lose expenses, and experience quality-of-life impacts [8]. Consequently, there is an increasing number of stroke survivors who are returning to reside in the community and who will require ongoing therapy and community support to assist with further recovery. To date, most of the research on stroke care focuses on acute stroke care and early rehabilitation in the hospital rather than living with chronic stroke in the community [9]. Evidence-based practice interventions for continuing care, which are culturally tailored, are required for health care services to promote positive outcomes, such as decreased morbidity and mortality rates for stroke patients after discharge.

In Thailand, the stroke rehabilitation service has three models: inpatient rehabilitation, outpatient rehabilitation and home-based rehabilitation. For inpatient rehabilitation, it is the most continuous and effective type of rehabilitation, but there are limitations in hospital beds, so patients only receive three to seven days of hospital treatment before their discharge. In the same vein, concerning the format of services provided today, patients have often facilitated rehabilitation in walking, which is used as an indicator for patients' eligibility for hospital discharge, but upper limb weakness and cognitive impairment are not given the same attention or are given little attention to after discharge, even they are correlated to quality of life [10]. At this point, their rehabilitation of upper limb disability and cognitive impairment would have not yet progressed sufficiently, and many patients try to compensate by using their other side that is still normal, thus leading to complications in the upper limbs and disability. Akinyemi et al. [11] also found that the most common complications after a stroke are pain 50%–80%, fatigue >80%. Consequently, Perin et al. [12] stroke patients, most of whom are older adults. There is a great need for rehabilitation, but they were unable to receive rehabilitation at the hospital due to the difficulty of traveling and the high cost. This is caused by a lack of awareness about rehabilitation services, the non-availability of rehabilitation services, and others, including a lack of family support, transportation, consulting appointments, and waiting time or the non-availability of health professionals. Therefore, home-based rehabilitation is one model to compensate for the lack of access to the rehabilitation system in hospitals, but it is an incomplete system due to a lack of rehabilitation equipment and personnel specializing in rehabilitation in community health services [13]. These examples reflect the problems of stroke survivors during the transition from the hospital to the community or their homes. Therefore, there must be continuous rehabilitation for the patient's function to recover as rapidly as possible.

This study was inspired by the statement by Rafael Salazar II, occupational therapist and president of Rehab U Practice Solutions, who offered that "technology has done a lot to improve both our understanding of complex medical and physiological issues, as well as decrease the barriers to delivering care directly to patients" [14]. The current study developed a new technology innovation called "FuekFone (F.F.) home-based program" to simultaneously promote recovery of the upper limbs and cognitive function by adhering to the principles of the design thinking process [15]. This program designed games for the Android system to promote simultaneous upper limb and cognitive rehabilitation, especially in home-based patients with limited access to the patient rehabilitation service system, and to encourage patients' ability to assist themselves and perform activities fully on their own to have a good quality of life. Thus, this study aimed to compare the effects of F.F. home-based program on the upper limb and cognitive functioning of ischemic stroke patients after discharge, 2 weeks, 4 weeks, and 6 weeks after discharge from hospital.

2. Methods

2.1. Study design and participants

This study adopted a single group pre-and post-test design to explore the effect of F.F. home-based program. The participants of this study consisted of ischemic stroke patients after discharge in the first six weeks from the stroke and neurological units of two university hospitals in Thailand who were suffering from upper limb function and cognitive impairments in addition to seeking outpatient rehabilitation.

Criteria for inclusion in the study were: 1) age over 18 years; 2) diagnosed with ischemic stroke by CT/MRI; 3) Modified Ashworth Scale (MAS) [16] score grade ranges between 0 and 2 (MAS was used to assess the resistance experienced during the range of motion, and a higher score indicates a higher degree of resistance of muscle); 4) diagnosed with ischemic stroke for the first time; 5) able to communicate in the Thai language; 6) a primary caregiver who may be a relative or someone who provides more care at home than anyone else and has a telephone that can be contacted and 7) there is a television at home that can receive signal and convert signal from android box. Exclusion criteria were: 1) upper limb disabilities that developed before receiving treatment for ischemic stroke; 2) diagnosed recurrent stroke; 3) the cause of the stroke must not be due to abnormalities in the blood vessels of the brain; 4) diagnosed with a psychological or psychiatric disorder before receiving treatment for ischemic stroke (those who had delusions of reality in their thoughts and hallucination) who were listed in the medical history before ischemic stroke treatment and 5) diagnosed with dementia or Alzheimer who were listed in the medical history before ischemic stroke treatment.

The G Power software package was used to calculate the sample size with an effect size of 0.37. This research doesn't know the effect size of the sample, so we used the concept of Cohen [17], which has a moderate effect size. Power of test (1-β err prob) at 0.80. This power of test was used in similar research in Högg et al. [18], number of measurement 3 (here were repeated three times for tests at weeks 2, 4, and 6 post-test). The total sample size was 37, with 3 additional participants added to prevent data attrition, thus leading the samples to 40 patients.

2.2. Ethical consideration

Ethics approval was obtained from Siriraj Hospital: MU-MOU CoA (No. IRB-NS2022/678.0104). All patients and their families have received informed consent and a participant information sheet from each setting.

2.3. Intervention procedure

Researchers implemented the intervention in two settings with the same level of the hospital as a university hospital. Therefore, the standard of care for patients at both hospitals would be the same due to the national standard guidelines. Moreover, the researcher was the one who implemented the intervention for both settings, so they had the same procedure when implementing the intervention.

2.3.1. Formation of the development team

The development of the F.F. home-based program consisted of three nursing instructors with strong experience in caring for stroke patients, who defined the research problems, outlined the concept, and acted as a leader of the research team. One engineering instructor with a background in medical design models designed and built this model, and one instructor from the faculty of science took action as a programmer to create and design a game in this program. We worked as a research team, an inter-faculty collaboration among three faculties and we had a petty patent no. 11174.

2.3.2. Development of the program

The F.F. home-based program is a device adapted from the original equipment used to rehabilitate patients with upper limb weakness, namely skateboards. Originally, it was found that patients could manage by moving their skates without movement direction. Therefore, the research team has modified it by connecting skateboards to Android games. So that patients can practice using their eyes, thinking, making decisions, and moving with direction in six games. This is a reaction called biofeedback, so it will help rehabilitate brain injuries [19]. The games in the F.F. home-based program were as follows. 1) Still Barrel, an exercise for patients to use fingers to press buttons for the barrel to open and receive things and close when things should not be received, helped patients exercise small muscles in the fingers. 2) Adventure Walk, an exercise for patients to use their hands to control the skateboards and direct a doll to move left or right according to the game's directions. This helped patients practice using large muscles and elbows in the abduction and abduction position. 3) Sliding Barrel, a game after Adventure Walk, helped patients practice using large muscles and shoulders in the abduction and abduction positions. 4) Sauce Squeezing, which continued after Adventure Walk, directed patients to use hand muscles and knuckles to squeeze the sliding board to make the sauce flow. 5) Chopping, a game after Adventure Walk, increased arm movement directions from left and right to forward and backward to chop things, which increased hand and shoulder muscles. 6) Picking Things Up, built on Adventure Walk and increased arm movement. It can record the name of each patient who plays the game. Each game has different difficulty and speed levels ranging from 1 to 10, and the maximum play time for each game is 10 mins. The games also have a feature that displays the scores achieved after playing the games.

2.3.3. The implementation of the program

Before discharge from the hospital, the researcher explained the procedures, usage methods, and potential risks with a video clip showing the details of the preliminary F.F. home-based program. Then, the researcher installed and tested this program at patients' homes with a user manual without charging. For the program's remote function, we used an Android box to connect to the TV without any remote control to adjust the TV. Participants only need to plug in, and then they can play games on the TV. In order to collect information about patients' activities, we provided participants with a paper form to record how long they played this program, as we recommended in our program. Moreover, the researcher called them to remind them to complete the paper form and any problems they had while using the program. After successfully installing and testing the innovation, the researcher allowed the patients and caregivers to practice using and experimenting with the F.F. home-based program in real life. In playing each game, the researcher assessed which game each participant must start with first. For example, those with arm weakness begin with the 3rd game. Each participant chose a different game according to their ability. The duration of playing the game: during the first week, the patients participate in the program for 24 min per time (once a day), 4 min each game, 3 days a week. The second week, let the patients play games for 30 min per time (once a day), 5 min each game, 3 days a week. Then, in the 3–6 weeks, let the patients play games for 1 h per time (once a day), 10 min each game, 5 days a week. It took six weeks to play the game because the literature review found that most recovery time will be 4–6 weeks, which is the golden period for stroke patients [20]. All games connected to the TV at participants' home.

2.4. Measures

The National Institutes of Health Stroke Scale, Thai version (NIHSS-T), the MAS, the Motor Assessment Scale, and the Comorbidity Scale are public tools that can be used without permission. The researcher received a certificate for using the Montreal Cognitive Assessment (MoCA) (No.THKUMYA710566092-01) and was trained in using the Motor Assessment Scale and the MAS tools correctly by a physiotherapist.

2.4.1. The demographic and clinical profile questionnaire

This questionnaire was used to collect patients' general information, including gender, age, marital status, level of education, occupation, income, etc.

2.4.2. The National Institutes of Health Stroke Scale, Thai version

The NIHSS assesses stroke severity, which was developed by the University of Cincinnati, the University of Iowa, the National Institutes of Health, and the National Institutes of Neurological Disorders and Stroke in the United States [21]. In this study, we used the NIHSS-T, which was validated by Nilanont et al. [22]. Intra-observer reliability demonstrated a high agreement with an intraclass correlation (ICC) of 0.98, 0.98, 0.96, 0.98, 0.90, and 0.98. Health service providers use this instrument to measure the severity of acute stroke. It contains 11 items; there are 4 levels, and total scores ranging from 0 to 42 scores (0 = no stroke symptoms, 1–4 = minor stroke, 5–15 = moderate stroke, 16–20 = moderate to severe stroke, 21–42 = severe stroke).

2.4.3. The Modified Ashworth Scale

This scale was created by Bohannon and Smith [23] and has six grades from 0 to 4, indicating rigidity in the extension or flexion position. A higher grade indicates increased muscle tone. Li et al. [24] studied test-retest reliability and inter-rater reliability of the Modified Tardieu Scale and the Modified in hemiplegic patients with stroke. For the MAS measurement, the inter-rater and intra-rater Kappa values were 0.66 and 0.69 for the elbow flexors 0.48 and 0.48 for the plantar flexors, respectively.

2.4.4. The Comorbidity Scale

The comorbidity was assessed by the Charlson Comorbidity Index (CCI) scale, which was developed by Charlson et al. [25]. The instrument was translated into Thai by Utriyaprasit and Moore and used in coronary artery bypass graph surgery patients [26]. The evaluation form covers 23 diseases, with score weights (CCI score) ranging from 0 to 42 points. Divided according to the severity of the disease. For example, hypertension = 1 point, leukemia = 2 points, severe liver disease = 3 points, AIDS = 6 points. A total score of 0 indicates no disease burden and higher scores indicate greater comorbidity. Total scores are in the range of 0–42 scores divided into four levels: 0 indicates no comorbidities; 1–2 scores indicate minor comorbidities; 3–4 scores indicate moderate comorbidities, and >5 scores indicate high comorbidities. The evaluation of the scores can be studied from the Charlson Comorbidity scale. Additionally, Suwanno et al. [27] used the instrument to assess heart failure patients and found the instrument's reliability to be 0.98.

2.4.5. The Motor Assessment Scale

This is an instrument used to assess physical movements and arm and leg function in stroke patients. It is based on normal movements and was designed by an Australian physical therapist [28]. It contains nine question items in total. The first six consist of an assessment of leg function, while the latter three consist of an assessment of arm function, such as the function of the upper arms, hand movements, and use of the hand to perform various activities. In Thailand, Phankaew et al. [29] used only the portion of the form for assessing upper limbs; it has 3 contains an assessment of 1) upper arm function, 2) hand movements, and 3) advanced hand activities. The interclass correlation coefficient of the total score of this scale was 0.998 ($P < 0.001$). The Kappa values of each part of this scale, upper arm function, hand movement, and advanced hand activities were 0.831, 0.826, and 0.829, respectively ($P < 0.001$). Scores are divided into 0–6 points, a total of 18 points. The mean score for each item is used, and a score higher than the initial assessment indicates upper limb function recovery.

2.4.6. The Montreal Cognitive Assessment

The MoCA assessed the cognitive. This assessment form is used to screen for patients with cognitive impairments and was developed by Nasreddine [30]. The Thai version was translated and validated by Hemrungrojn [31]. There consists of 8 dimensions (11 items): 1) visuospatial/executive (1 item); 2) naming (1 item); 3) memory(1 item); 4) attention (3 items); 5) language (2 items); 6) abstraction (1 item); 7) delayed recall (1 item); 8) orientation (1 item). There are 30 points, with one additional point given to persons with education below or equal to primary school (grade six). The instrument's sensitivity was 90% and specificity 87%. Interpretation of Results Patients with MoCA scores below or equal to 25 were considered to have cognitive impairments [31].

2.5. Data collection

The study shows that data were collected in two settings where the quality of data collection was controlled by both hospitals, which are superior tertiary hospitals and the patient rehabilitation systems have similar characteristics. When the patients are discharged from the stroke unit, a doctor gives orders, and patients have to follow up at outpatient rehabilitation to monitor symptoms and receive advice from a multidisciplinary team in rehabilitation. These data were collected during June 2022–January 2023.

Patients were approached on 3–5 days in the stroke unit and were invited to participate in the study. After the participants received F.F. home-based program, the researcher explained the procedures and assessed readiness. Then, install and test this program at participants' homes. The participants were asked for demographic information, and the study instruments were administered. The researcher conducted the interview and assessment face-to-face and took approximately 40 min to complete. The researcher collected information about the patient's clinical characteristics from the medical record at discharge (T1). Measure of outcome variables were repeated at 2 weeks (T2), 4 weeks (T3), and 6 weeks (T4) after discharge, because these periods are the effective periods for motor and cognition recovery [32,33].

2.6. Data analysis

The Statistical Package for the Social Sciences (SPSS Inc.) for Windows, version 25.0, was used for data entry and analysis. Continuous variables were described as either mean (standard deviation) or median (P_{25}, P_{75}), where categorical variables were given as frequency and percentage. The Friedman test was used to answer the research questions and see the program's effect, with a significant level set at 0.05. A Bonferroni post hoc correction was adopted to identify pairwise differences.

3. Results

3.1. Demographic of participants

Table 1 presents the total participation rate of 100% ($n = 40$), and the mean age was 62.60 ± 11.73 years. Most participants were male, 72.5%, and married accounted for 72.5%. They had finished at lower than a bachelor's degree, accounting for 72.5%. Most of them did not work, 52.5%. The severity of ischemic stroke was moderate stroke to severe stroke, which accounted for 72.5%, and cognitive impairment in the MoCA score accounted for 25%. For comorbidities, it was found that the comorbidities were at a minor comorbidities level, which was 65%, as shown in Table 1.

3.2. Effect of the intervention

The results found that participants had statistically improved upper limb function (upper arm function score, hand movements score, advanced hand activities score, total Motor Assessment Scale score) and cognitive function (MoCA score) at 2, 4, and 6 weeks after discharge ($P < 0.001$). In the comparison of upper limb function and cognitive function at each of the study times, we found statistically improved upper limb function (upper arm function score, hand movements score, advanced hand activities score, total Motor Assessment Scale score) and cognitive function (MoCA score) at 4, and 6 weeks after discharge when compared to after discharge and 2 weeks after discharge, respectively ($P < 0.05$). Moreover, the total Motor Assessment Scale score was statistically significant between 2 weeks and 4 weeks after discharge ($P < 0.05$). However, upper arm function scores, hand movement scores, advanced hand activity, total Motor Assessment Scale score, and MoCA scores were not significant between after discharge and 2 weeks after discharge, between 2 weeks and 4 weeks after discharge, and between 4 weeks and 6 weeks after discharge

Table 1
The demographic variables of patients (n = 40).

Characteristic	n (%)
Gender	
Male	29 (72.5)
Female	11 (27.5)
Age (years)	
18–59	13 (32.5)
60 or older	27 (67.5)
Marital Status	
Single	11 (27.5)
Married	29 (72.5)
Level of education	
Lower than bachelor's degree	29 (72.5)
Bachelor's degree or higher	11 (27.5)
Occupation	
Did not work	21 (52.5)
Employee	19 (47.5)
Incomes (Baht/month)	
<4,000	12 (30.0)
≥4,000	28 (70.0)
Severity of ischemic stroke (NIHSS-T)	
No stroke/minor stroke	11 (27.5)
Moderate stroke to severe stroke	29 (72.5)
MAS score	
Grade 0	35 (87.5)
Grade 1	3 (7.5)
Grade 1+	1 (2.5)
Grade 2	1 (2.5)
Grade 3	0
Grade 4	0
MoCA score	
< 25 (cognitive impairment)	10 (25.0)
≥ 25 (no cognitive impairment)	30 (75.0)
Comorbidities	
No comorbidities	11 (27.5)
Minor comorbidities	26 (65.0)
Moderate to high comorbidities	3 (7.5)

Note: NIHSS-T = the National Institutes of Health Stroke Scale, Thai version. MoCA = The Montreal Cognitive Assessment. MAS = Modified Ashworth Scale.

(P > 0.05). Table 2.

4. Discussion

The F.F. home-based program can improve upper limb function in upper arm function, hand movement function, advanced hand activity, and total arm function at 2, 4, and 6 weeks after discharge (P < 0.001). This may be explained by how stroke patients could recover because brain cells were able to recover. Although parts of the brain were permanently damaged by ischemia, nearby parts of the brain, including the opposite side of the brain, were usually able to function in place of one another, causing patients to have improved symptoms [34]. In addition, increased efficiency of blood circulation to brain tissues when collateral circulation occurs helps nerve cells recover effectively [35].

Additionally, the F.F. home-based program consisted of six games for exercising upper limbs with skateboards to support the limbs because most patients initially had arm muscle fatigue and could not raise their arms. It had six directions: center, front, left, right, diagonal left, and diagonal right, which increased the use of hand and shoulder muscles in the abduction and abduction positions. The study was consistent with previous studies that found the use of a mobile upper extremity rehabilitation program, using a smartphone and a tablet PC in which the experimental group was found to have higher evaluation scores for upper limb function, Brunnstrom stage scores, and higher manual muscle testing scores than the control group were found with statistical significance. Moral-Muñoz et al. [36], in a meta-analysis about Game-Based Virtual Reality Interventions to Improve Upper Limb Motor Function, found that VR interventions can improve upper limb. This is consistent with the study of Saita et al. [37], who studied the biofeedback effect of hybrid assistive limbs. They found similarly that the mean number of flexion/extension movements within 15s increased significantly and the cortical activation is increased in the primary motor cortex of the hemisphere immediately after the hybrid assistive limb-single-joint treatment compared to the baseline condition in stroke patients. However, Laffont and colleagues [38] study about the rehabilitation of the upper arm early after a stroke found that video games can improve the upper arm versus conventional rehabilitation, but in general, it cannot conclude that video gaming and conventional occupational therapy (OT) led to different long-term.

For cognitive function (MoCA scores), the F.F. home-based program can improve cognitive function at 2, 4, and 6 weeks after discharge. A possible reason is this program may have encouraged cognitive recovery because of the six games were simple to play and imitated activities in daily living. For example, the third game of this program (the moving tanks) stimulates cognitive recovery by using the principles of brain stimulation according to the eight aspects of the MoCA. 1) Orientation: the game stimulates since the patient perceives visually that an object is falling and must move the arm to pick up the item in time. 2) Executive function: games help patients practice moving their arms to the left or right to receive the objects, which helps patients practice management when picking up the left side and how to move the adjusting arm of the left side to catch up when playing games at a speed level. 3) Memory: games help patients practice memory. The patient must remember not to accept the red ball, as points would be deducted. 4) Attention/concentrate: the game would train patients to practice attention or concentrate on completing the game when time is up. 5) Calculation: this aspect may not directly train the patient to use numerical calculation skills, but it would practice calculating the distance of pick-up to determine how long or short the distance of the skateboard has to be to pick up. 6) Delayed recall: games would help patients practice short-term memory, namely remembering that when the object falls on the left side, the skateboard must be moved to the left, or when the object falls in the middle, the skateboard must be moved to the middle, etc. 7) Naming: this game will practice calling objects when something falls. The patient can practice calling the name of the falling object. 8) Abstraction: picked in this game by letting the patient distinguish that the red ball, when falling, must not be picked up because points will be deducted, and when other objects fall, if not, the red ball can pick up the object because it would earn points.

The studies conducted in the past were found to have included studies on cognitive recovery models, such as a study conducted by Wei et al. [39] about the effect of early cognitive training and rehabilitation of patients with cognitive dysfunction in stroke by measuring results at four weeks post-test, which found the cognitive reaction time was shorter than that before treatment. In addition, a study conducted by Thaivon & Munkhetvit [40] on the effects of applications on computer tablets for cognitive training in patients with stroke by measuring results six weeks after the program found the improvement of attention, memory, and executive functions to have similarly reached statistical significance.

The comparison effect of F.F. home-based program on upper limb function and cognitive function at each of the study times, we found statistically improved upper limb function (upper arm function score, hand movements score, advanced hand activities score, total Motor Assessment Scale score) and cognitive function (MoCA score) at 4, and 6 weeks after discharge when compared to after discharge and 2 weeks after discharge, respectively (P < 0.05). A possible reason similar to the above is that the upper limb

Table 2
Comparison of pre- and post-intervention outcomes among patients ($n = 40$).

Variables	T1	T2	T3	T4	F for time	P	Pairwise comparisons
Total Motor Assessment Scale score	3.5 (0.0, 13.0)	11.0 (1.0, 15.0)	14 (1.3, 18.0)	15.5 (3.0, 18.0)	128.353	<0.001	T3 > T1; T4 > T1; T3 > T2; T4 > T2
Upper arm function score	3.0 (0.0, 6.0)	3.5 (1.0, 6.0)	6.0 (1.3, 6.0)	6.0 (3.0, 6.0)	42.507	<0.001	T3 > T1; T4 > T1; T4 > T2
Hand movements score	0.0 (0.0, 5.0)	3.5 (0.0, 6.0)	5.0 (0.0, 6.0)	6.0 (0.0, 6.0)	23.602	<0.001	T3 > T1; T4 > T1; T4 > T2
Advanced hand activities score	0.0 (0.0, 3.0)	1.0 (0.0, 5.0)	3.0 (0.0, 6.0)	5.0 (0.0, 6.0)	24.505	<0.001	T3 > T1; T4 > T1; T4 > T2
MoCA score	26.0 (23.5, 27.8)	26.0 (24.3, 28.0)	26.0 (25.0, 28.0)	27.0 (25.0, 28.0)	33.018	<0.001	T3 > T1; T4 > T1; T4 > T2

Note: Data are *Median* (P_{25}, P_{75}). All P<0.05. T1: after discharge; T2: 2 weeks after intervention; T3: 4 weeks after intervention; T4 = 6 weeks after intervention. MoCA = The Montreal Cognitive Assessment.

function and cognitive function need more times than 2 weeks, such as 4 or 6 weeks, for better neuron recovery. This study is consistent with the study by Budhota and colleagues [41] about robotic-assisted upper limb training post-stroke with measurements of results at 3, 6, 12, and 24 weeks; the robotic therapy group was found to have similarly improved clinical scores when compared to the conventional therapy group with no significant inter-group variation at all time points throughout the conventional therapy. However, the total Motor Assessment Scale score was statistically significant even in a short period between 2 weeks and 3 weeks after discharge. It may indicate the total upper limb function can recover during a golden period, which is in the first 4 weeks after discharge [42], consistent with the study of Oh et al. [43], which similarly measured results at 4 weeks. The experimental group showed greater therapeutic effects in a time-dependent manner than the control group in terms of motor power of wrist extension, spasticity of elbow flexion and wrist extension, and Box and Block Tests.

In contrast, upper arm function scores, hand movement scores, advanced hand activity scores, total Motor Assessment Scale scores, and MoCA scores were not significant between the time at discharge and 2 weeks after discharge, 2 and 4 weeks after discharge, and 4 and 6 weeks after discharge. This may be explained by the trial period being very short (2 weeks), so motor and cognitive function cannot be identified clearly in recovery.

There are limitations to this study. First, the sample of this study is small, that needs to be expanded in future studies. Second, it is using F.F. home-based program found that the steps to use are difficult, such as some functions of the program may be complicated for older or low technology skills patients and caregivers, so the new version of this program should be adjusted to make it easy to use, such as adjusting the process of accessing the game to be easier than before. Third, this study should have a control group to compare the effect of F.F. home-based program more appropriately.

5. Conclusion

The F.F. home-based program is beneficial for improving recovery outcomes for patients with upper limb weakness and cognitive impairments at discharge and 2 weeks, 4 weeks, and 6 weeks after discharge from the hospital. This program should be used for rehabilitation to promote stroke patients' motor and cognitive function at home during the rehabilitation period. Future studies should provide patient training on how to administer the F.F. home-based program and measure outcomes for a longer period of follow-up, more than 3 months, with a control group.

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Nothing to declare.

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

CRediT authorship contribution statement

Yaowalak Kumkwan: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Project administration. **Ketsarin Utriyaprasit:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - review & editing, Supervision, Project administration. **Thitipong Tankumpuan:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - review & editing. **Zeng Lertmanorat:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources. **Boonyanit Mathayomchan:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources.

Declaration of competing interest

The authors declare that they have no competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnss.2024.08.008.

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