Effect of Home-based Telerehabilitation on the Postoperative Rehabilitation Outcome of Hip Fracture in the Aging Population

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Objective: To investigate the effects of home-based telerehabilitation based on the Internet-based rehabilitation management system on hip function, activities of daily living and somatic integrative ability of elderly postoperative hip fracture patients.

Methods: From June 2020 to November 2020, we recruited 58 elderly postoperative hip fracture patients and randomly assigned them to the telephone group (n = 29) and the telerehabilitation group (n = 29). Both groups received routine discharge instructions, and the former received telephone follow-up after discharge, while the latter received remote rehabilitation based on the Internet-based rehabilitation management system. The Harris hip score (HHS), functional independence measure (FIM), timed up-and-go test (TUG), and short physical performance battery (SPPB) were used to evaluate the patients’ hip function, activities of daily living, and overall somatic ability.

Results: There was no significant difference between the baseline data of the two groups before the intervention (P > 0.05); no matter after hip replacement or internal fixation, the HHS score and FIM score of both groups increased gradually with the postoperative time, and the scores in the telerehabilitation group were higher than those in the telephone group at 1 and 3 months after the intervention, and the difference was significant (P < 0.05); for patients after hip replacement, the TUG and SPPB scores in the telerehabilitation group were better than those in the telephone group at 3 months after the intervention, and the difference was significant (P < 0.05).

Conclusions: The Internet-based rehabilitation management system applied to postoperative home rehabilitation of elderly hip fracture patients can improve the functional recovery of the hip joint and enhance the ability to perform activities of daily living and somatic integration to a certain extent. This seems to provide an effective option for conducting home rehabilitation.

Key words: Hip fracture; Internet-based intervention; Older adults; Telerehabilitation

Introduction
Osteoporotic fractures of the hip in the elderly are a negative consequence of the interconnectedness of social aging and osteoporosis, with high rates of disability and mortality.¹ ² This not only adversely affects the quality of life of individuals, but also places a heavy burden on the families and society. Elderly patients with hip fractures generally have complex physical conditions, and some studies have shown that 75.2%–82% of patients have coexisting medical conditions, and 37.6%–38% of patients have more than two coexisting conditions.³ Hip fractures mainly include femoral neck fractures (FNF) and intertrochanteric fractures (IF), and the surgical methods mainly include hip replacement and internal fixation. In 2014, the American Academy of Orthopedic Surgeons (AAOS) formulated the guidelines for the management of hip fracture in the elderly, which said that moderate evidence supports that hip fracture surgery within 48 h of admission is associated with better outcomes.⁴

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The concept of enhanced recovery after surgery (ERAS) is advocated to be applied to the perioperative treatment of elderly hip fractures at home and abroad in recent years. Although the treatment has improved to some extent, the prognosis remains controversial. Less than half of the patients will return to the level of physical function before the fracture, and the mortality rate reaches 15%–33% within 1 year after the fracture. After hip fracture surgery, patients are negatively affected in physical, psychological and social aspects, and their quality of life is also reduced. A rehabilitation approach should start as early as possible to prevent complications, and should include multidisciplinary care. The recovery of physical function of patients after discharge mostly occurs in the first 3–6 months after fracture, which is a critical period for rehabilitation.

Due to the rapid postoperative turnaround time, shortened patient hospitalization days, and COVID-19 epidemic prevention and control, most of the postoperative rehabilitation exercises are conducted outside the hospital. Home rehabilitation is a rehabilitation model that extends rehabilitation training from the hospital to home. The common type of home rehabilitation is telephone follow-up and regular hospital outpatient review. With rapid development of Internet technology and strong support of national policies in recent years, “Internet + medicine” has become an emerging medical service model, which provides a platform for remote rehabilitation and an important means for the orderly resumption of medical services based on epidemic prevention and control. Telerehabilitation refers to the remote delivery of different rehabilitation services via telecommunications technology, including physiotherapy, speech therapy, occupational therapy, patient telemonitoring and teleconsultation.

Relevant literature reports that the home-based telerehabilitation is helpful to promote the recovery of hip joint function of elderly patients with hip fracture, improve the quality of life and psychological factors to a certain extent. At present, Internet-based remote rehabilitation is mainly carried out in the form of application software and website with smart devices such as mobile phones and computers as the carrier. Bedra et al. used a remote rehabilitation management system to help 10 hip fracture subjects receive individualized training and rehabilitation education, and they found that this rehabilitation model was safe and effective, with significant improvements in patients’ physical function and quality of life, but the small sample size and the absence of a control group were the major shortcomings of their study. Ortiz et al. designed a 12-week multidisciplinary home rehabilitation program to guide patients with hip fractures through a website platform for physical therapy and occupational therapy. Pol et al. combined a website platform with sensors to monitor patients’ daily activities and regularly adjusted the rehabilitation program based on objective information from sensor feedback, and the results showed that sensor-based monitoring of home rehabilitation could effectively improve the daily activity function of elderly hip fracture patients. However, the current research evidence is still limited, with different remote technologies, different experimental design. It also needs the support of a large number of high-quality randomized controlled trials.

The “Family-oriented postoperative rehabilitation management system for geriatric hip fracture” (referred to as “rehabilitation management system”) was used to provide remote rehabilitation services for elderly postoperative hip fracture patients. It is a new Internet-based home rehabilitation management platform that uses the combination of offline terminal equipment and online cloud platform, which allows the patients to use the offline terminal equipment to complete the collection of vital signs and rehabilitation within the prescribed scope at home, and transmit these data to the cloud platform built by the hospital through video, questionnaire, chat, and other forms. Therefore, in order to explore and provide a more effective and feasible home rehabilitation intervention strategy for patients, we conducted this study, which aims to: (i) compare the effects of telephone follow-up and home-based telerehabilitation on the hip function of elderly patients after hip fracture surgery; (ii) observe the activities of daily living of postoperative patients; and (iii) evaluate the effect of home-based telerehabilitation on the somatic integrative ability of postoperative patients.

Materials and Methods

General Data and Grouping

A randomized controlled trial was used to select elderly patients with osteoporotic hip fractures, including FNFs and IFs, who were hospitalized in the Department of Hip Trauma of Tianjin Hospital in Tianjin, China, from June 2020 to November 2020. This study was approved by the Ethics Committee of the Tianjin Hospital (2022-079). Informed consent was obtained from all patients.

Inclusion and Exclusion Criteria

Inclusion criteria: (i) low-energy injury resulting in unilateral hip fracture treated with first hip arthroplasty or internal fixation; (ii) age ≥60 years; (iii) no limb dysfunction before the fracture and independent living ability (functional independence measure (FIM) ≥90 points); (iv) condition had settled, and the patient can cooperate with rehabilitation treatment and had no cognitive dysfunction (mini-mental state examination (MMSE) ≥24 points); (v) presence of a family caregiver and the patient or caregiver had a smartphone; and (vi) patients and family members voluntarily participated in the study and signed the informed consent form.

Exclusion criteria: (i) pathological fractures; and (ii) in combination with serious chronic diseases, such as heart, liver, and lung diseases. Drop-out criteria: (i) those who voluntarily withdrew from the study; and (ii) those who received treatment midway from a rehabilitation institution.

A total of 58 elderly postoperative patients with hip fracture were included in this trial, and they were assigned to...
either the telephone group or the telerehabilitation group using the random number table method, with 29 cases in each group. Seven patients were withdrawn during the intervention, and finally, there were 27 cases in the telerehabilitation group (20 cases of FNF and seven cases of IF) and 24 cases in the telephone group (16 cases of FNF and eight cases of IF). FNFs and IFs were classified according to the Gardens classification and the AO classification respectively, and IFs were divided into stable fractures (A1.1-A2.1) and unstable fractures (A2.2-A3.3).\textsuperscript{17,18} Both groups of patients underwent surgery within 48 h of admission. There were 17 cases of hip replacement and 10 cases of internal fixation in the telerehabilitation group and 14 cases of hip replacement and 10 cases of internal fixation in the telephone group. The differences in general basic information and relevant medical history information between the two groups were not significant ($P > 0.05$) and were comparable, as shown in Table 1.

### Treatment Methods
Patients in both groups received routine discharge instructions 1–2 days after surgery: bedside rehabilitation instructions and health education, including ankle pump exercises, heel gliding exercises, quadriceps contraction training, breathing exercises, and prevention of postoperative complications, dietary instructions, etc. The subjects included in this study were mostly bedridden at the time of discharge.

### Table 1: Comparison of general information between the two groups of patients

| Items                                           | Telerehabilitation group ($n = 27$) | Telephone group ($n = 24$) | $\chi^2$/$t$/$z$ | $P$  |
|------------------------------------------------|-----------------------------------|---------------------------|------------------|------|
| Gender                                         |                                   |                           |                  |      |
| Male                                           | 10                                | 8                         | 0.076\textsuperscript{a} | 0.782 |
| Female                                         | 17                                | 16                        | 0.836\textsuperscript{c} | 0.407 |
| Age (Mean ± SD · years)                        | 77.00 ± 7.89                      | 75.17 ± 7.73              | 0.854\textsuperscript{a} | 0.562 |
| Education level                                |                                   |                           |                  |      |
| Primary School or below                        | 7                                 | 9                         | 0.743\textsuperscript{a} | 0.398 |
| Middle School                                  | 10                                | 7                         | 0.899\textsuperscript{a} | 0.418 |
| High School/Secondary School                   | 6                                 | 4                         | 0.608\textsuperscript{a} | 0.412 |
| College or above                               | 4                                 | 4                         | 0.527\textsuperscript{a} | 0.686 |
| Marital status                                 |                                   |                           |                  |      |
| Unmarried                                      | 0                                 | 1                         | 0.863\textsuperscript{a} | 0.707 |
| Married                                        | 21                                | 17                        | 0.686\textsuperscript{a} | 0.678 |
| Widowed                                        | 6                                 | 6                         | 0.686\textsuperscript{a} | 0.678 |
| Primary caregiver                              |                                   |                           |                  |      |
| Spouse                                         | 9                                 | 5                         | 0.863\textsuperscript{a} | 0.707 |
| Child                                          | 14                                | 13                        | 0.686\textsuperscript{a} | 0.678 |
| Others                                         | 4                                 | 6                         | 0.686\textsuperscript{a} | 0.678 |
| Fracture type                                  |                                   |                           |                  |      |
| Femoral neck fracture                          | 20                                | 16                        | 0.336\textsuperscript{b} | 0.527 |
| Intertrochanteric Fracture                     | 7                                 | 8                         | 0.562            |      |
| Classification of femoral neck fracture (Gardens) |         |                           |                  |      |
| I                                              | 5                                 | 4                         | 0.899\textsuperscript{a} | 0.418 |
| II                                             | 0                                 | 0                         | 0.863\textsuperscript{a} | 0.707 |
| III                                            | 12                                | 8                         | 0.863\textsuperscript{a} | 0.707 |
| IV                                             | 3                                 | 4                         | 0.863\textsuperscript{a} | 0.707 |
| Classification of Intertrochanteric Fracture (AO) |             |                           |                  |      |
| Stable fractures                               | 3                                 | 2                         | 0.608\textsuperscript{a} | 0.418 |
| Unstable fractures                             | 4                                 | 6                         | 0.608\textsuperscript{a} | 0.418 |
| Surgical method                                |                                   |                           |                  |      |
| Total hip replacement                          | 12                                | 11                        | 0.866\textsuperscript{d} | 0.707 |
| Hemiarthroplasty                               | 5                                 | 3                         | 0.866\textsuperscript{d} | 0.707 |
| Internal fixation                              | 10                                | 10                        | 0.866\textsuperscript{d} | 0.707 |
| Complication                                   |                                   |                           |                  |      |
| None                                           | 4                                 | 5                         | 0.863\textsuperscript{a} | 0.707 |
| 1                                              | 8                                 | 6                         | 0.863\textsuperscript{a} | 0.707 |
| 2 or more                                      | 15                                | 13                        | 0.863\textsuperscript{a} | 0.707 |
| Postoperative complications                    |                                   |                           |                  |      |
| None                                           | 22                                | 21                        | 0.707\textsuperscript{a} | 0.678 |
| 1                                              | 5                                 | 3                         | 0.707\textsuperscript{a} | 0.678 |
| Post-operative hospitalization time (mean ± SD · days) | 4.30 ± 1.71  | 4.13 ± 0.99 | −0.416\textsuperscript{d} | 0.678 |
| MMSE (mean ± SD)                               | 27.59 ± 1.58                      | 27.21 ± 1.64              | 0.853\textsuperscript{c} | 0.398 |
| Pre-fracture FIM (Mean ± SD)                   | 114.85 ± 5.16                     | 113.46 ± 6.97            | 0.817\textsuperscript{c} | 0.418 |

Abbreviation: MMSE, Mini-mental State Examination. Notes: \textsuperscript{a}Fisher’s exact probability test; \textsuperscript{b}The $\chi^2$ value; \textsuperscript{c}The $t$ value; \textsuperscript{d}The $z$ value.
and early weight-bearing activities were possible after hip arthroplasty; however, the duration of weight bearing after internal fixation was determined according to the degree of fracture-induced damage and callus formation. At the same time, the general physical condition of the patients should be taken into consideration. The duration of weight bearing in all patients in the study group was at the surgeon’s discretion. At discharge, a paper version of the “Postoperative Home Rehabilitation Manual for Geriatric Hip Fractures” was issued to the patients and their families for their reference and study. Further, patients were instructed to visit the outpatient clinic for review at 1 and 3 months after surgery.

The two types of surgery are different, and the rehabilitation process after the two kinds of procedures are different. Patients after hip replacement need to pay attention to some taboo actions, such as hip flexion not more than 90° and preventing hip adduction. The rehabilitation goal of the two types of surgery is different, and the rehabilitation management system for geriatric hip fractures developed by our department was used for home-based telerehabilitation. The system consisted of a physician side—a website platform, and a patient side—an application (APP) installed on a smartphone. Before discharge, patients or their family members signed an informed consent form and downloaded and installed the patient APP by scanning a QR code on their smartphones. The researcher (Z.Y.Y.) logged into the doctor’s side of the system and entered the patients’ basic information and medical history; informed them how to log into the patient side; introduced the purpose of each function bar; and demonstrated how to communicate and interact with the doctor’s side, view health prescriptions and rehabilitation lectures, and fill out follow-up questionnaires. The specific intervention steps were as follows (Fig. 1).

**The Telerehabilitation Group**

The patients in the telerehabilitation group were discharged from the hospital, and a “home-oriented post-operative rehabilitation management system for geriatric hip fractures” developed by our department, was used for home-based telerehabilitation. The system consisted of a physician side—a website platform, and a patient side—an application (APP) installed on a smartphone. Before discharge, patients or their family members signed an informed consent form and downloaded and installed the patient APP by scanning a QR code on their smartphones. The researcher (Z.Y.Y.) logged into the doctor’s side of the system and entered the patients’ basic information and medical history; informed them how to log into the patient side; introduced the purpose of each function bar; and demonstrated how to communicate and interact with the doctor’s side, view health prescriptions and rehabilitation lectures, and fill out follow-up questionnaires. The specific intervention steps were as follows (Fig. 1).

**Delivery of Personalized Rehabilitation Programs, Rehabilitation Videos, and Health Knowledge**

The investigator based on the physician’s recommendation developed a personalized rehabilitation program and pushed it to the patient’s APP, including the content of rehabilitation training, management of underlying diseases, and post-operative precautions. The rehabilitation program was adjusted according to the remote assessment results during the intervention period. The system could automatically send rehabilitation videos and health information based on the patient’s condition and the number of days after surgery. For example, 1 week after surgery, videos on breathing training, muscle training in bed, and related health knowledge were automatically sent to the patients who underwent hip arthroplasty; videos on contraindicated and correct movements were automatically sent to patients who underwent hip replacement. Functional training videos, such as walking, balancing, and stair walking, were manually provided to the patients based on the assessment results. Patients could watch the rehabilitation videos after they were discharged from the hospital, learn about their health, and perform appropriate rehabilitation according to their personalized rehabilitation program. In addition, doctors could check whether the patients had watched the rehabilitation materials so that they can be reminded to watch these materials on time.

**Remote Monitoring of Vital Signs**

Patients and their family members used wearable devices, including infrared thermometers, blood pressure and heart rate meters, to regularly measure the patient’s vital signs at home, and they transmitted these data to the physician side based on the Internet of Things and Internet technology. Researchers could monitor and track the patient’s health in real time and grasp the patient’s postoperative recovery, which provided a scientific basis for the next rehabilitation.
Remote Assessment and Guidance

At 2 weeks, 1 month, 2 months, and 3 months after discharge, remote video assessment and guidance, mainly including the following were conducted.

Assessment and guidance of home environmental risk factors: home environmental risk factors were assessed during the first remote video and guidance were provided on environmental modification. For example, adequate lighting was provided for all activity areas and basic lighting at night; handrails and anti-slip mats were installed in the bathroom; a raised toilet seat or a higher toilet seat was used.

Wound assessment and care guidance: the patient’s family was asked to point the cell phone camera at the wound site and observe the size of the wound, any inflammatory manifestations around the wound, and any exudation. If there was any abnormality, the patient was reminded to seek medical attention in time. The patient was advised to keep the dressing area clean and dry on a daily basis and change the dressing every 2–3 days for 2 weeks after surgery.

Pain assessment and guidance: the degree of pain around the hip was used using the visual analogue scale (VAS) pain scale, and the time, nature, and extent of pain were recorded. If the pain worsened after exercise or in the evening, the patient was advised to use ice therapy to relieve the pain and moderately reduce the amount and intensity of exercise; if the pain was persistent and did not ease after adjusting the rehabilitation program, the patient was advised to seek medical attention promptly.

Assessment and guidance of activities of daily living: the modified Barthel index was used to assess the ability for activities of daily living, and patients were encouraged and guided to complete the activities of daily living independently within a safe range and to use assistive devices to reduce their dependence on others. In addition, relevant rehabilitation videos were introduced for their reference and learning.

Motor function assessment and guidance: The patient was asked to demonstrate the current stage of rehabilitation training items and to show correct irregular training movements. Through observation of the patient’s limb movements, muscle strength, joint range of motion, and functional mobility were determined. The rehabilitation program was adjusted according to the assessment results, the next stage of rehabilitation training was guided, and relevant rehabilitation videos and personalized rehabilitation programs were pushed out.

Psychiatric assessment and guidance: the Anxiety Screening Questionnaire (GAD-7) and the Patient Health Questionnaire Depression Subscale (PHQ-9) were used to understand the patients’ psychiatric conditions and to provide corresponding psychological support.
Assessment and guidance of common complications: for example, Caprini score and Braden score were used to assess the risk of deep vein thrombosis and pressure sores, respectively.

Interactive question and answer: various problems encountered by the patients in rehabilitation exercise and questions from family members on caregiving were answered.

**Appointment for Consultation**
If patients had rehabilitation problems at other times, patients and family members could make appointments for consultation through the patient APP and could choose to communicate and interact with the doctor in various forms of video, voice, or text.

**Effectiveness Evaluation**

**Harris Hip Score**
The HHS, a scale widely used at home and abroad to assess hip function includes the following four aspects: pain, function, deformity, and joint mobility. The total score is 100, and the higher the score, the higher the level of hip function.

**Functional Independence Measure**
The functional independence measure (FIM) scale has been used as a post-discharge follow-up assessment test for hip fracture patients and consists of 18 items that rate patients’ somatic, verbal, social, and cognitive functions. The lowest score is 18 and the highest score is 126. Higher scores indicate higher levels of functional independence and lower levels of dependence, i.e., higher ability to perform activities of daily living.

**Timed Up and Go Test**
The timed up-and-go test (TUG) is a simple and rapid test that does not require special equipment or training to assess the functional walking ability and predict fall risk in older adults. The patient sits in a reclining chair, stands up at the command “Start,” stands still, walks forward 3 m at the usual pace, and then turns around and returns to the chair and sits down. The assessor records the time (s) taken by the patient to execute the command and sit back in the chair, without giving the patient any physical contact assistance during the test. Three tests were performed and the best result was obtained. The shorter the time taken, the better the balance function and walking ability, and the lower the risk of fall.

**Short Physical Performance Battery**
The Short physical performance battery (SPPB) is a comprehensive assessment index used to assess the motor ability of the elderly and to predict the risk of falls. It consists of the following three components: balance test, gait speed test, and five sit-to-stand test, which assess static and dynamic balance, lower limb strength, and gait speed. The SPPB score ranges from 0 to 12, and the higher the score, the better the overall somatic ability and the lower the risk of fall.

**Data Collection Method**
Data collection of general basic information and relevant medical history information was completed before the patients were discharged from the hospital. The scores of HHS and FIM scale were collected by specialized assessors at the hospital outpatient clinic at 1 and 3 months following the intervention, and the assessment tests of TUG and SPPB were completed at 3 months following the intervention by adopting uniform test methods and assessment criteria.

**Statistical Analysis**
SPSS statistical software (version 23.0, IBM, Armonk, NY, USA) was used to process and analyze the data. The HHS score, FIM score, SPPB scores and TUG scores were normally distributed, and they were compared between and within groups using independent sample t-tests and paired sample t-tests and were expressed as “mean ± standard deviation (Mean ± SD).” Two-factor repeated measures ANOVA was used to compare the longitudinal trends of HHS scores and FIM scores at different time points in the two groups. All tests were performed at $P < 0.05$ to indicate a significant difference.

**Results**

**Comparison of Hip Function Between the Two Groups**

**After Hip Replacement**
The difference in baseline HHS score between the two groups was not significant ($P > 0.05$). The HHS score in the telerehabilitation group was higher than that in the telephone group ($F = 5.393, P = 0.027 < 0.05$). The HHS score in both groups increased gradually with the change in postoperative time ($F = 118.407, P = 0.000 < 0.05$), and the increase in the scores in the telerehabilitation group was greater than that in the telephone group ($F = 5.811, P = 0.008 < 0.05$). The scores in both groups at 1 and 3 months after the intervention were significant compared to the pre-intervention scores ($P < 0.017$). The telerehabilitation group scores were higher than the telephone group scores at 1 and 3 months after the intervention (the mean were higher than 6.83 and 8.34 respectively), and the difference was significant ($P < 0.05$), as shown in Table 2.

**After Internal Fixation**
The difference in baseline HHS score between the two groups was not significant ($P > 0.05$). The HHS score in the telerehabilitation group was higher than that in the telephone group ($F = 13.429, P = 0.002 < 0.05$). The HHS score in both groups increased gradually with the change in postoperative time ($F = 84.475, P = 0.000 < 0.05$), and the increase in the scores in the telerehabilitation group was
greater than that in the telephone group ($F = 3.386$, $P = 0.045 < 0.05$). The scores in both groups at 1 and 3 months after the intervention were significant compared to the pre-intervention scores ($P < 0.017$). The telerehabilitation group scores were higher than the telephone group scores at 1 and 3 months after the intervention (the mean were higher than 7.20 and 11.60 respectively), and the difference was significant ($P < 0.05$), as shown in Table 3.

**Comparison of Activities of Daily Living Ability Between the Two Groups**

**After Hip Replacement**

There was no significant difference between the baseline FIM scores in the two groups ($P > 0.05$). The FIM scores in the telerehabilitation group were higher than those in the telephone group ($F = 24.992$, $P = 0.000 < 0.05$). The FIM scores in both groups increased with time postoperatively ($F = 706.689$, $P = 0.000 < 0.05$), and the increase in scores in the telerehabilitation group was greater than that in the telephone group ($F = 8.723$, $P = 0.000 < 0.05$). The scores in both groups at 1 and 3 months after the intervention were significant compared to those at pre-intervention ($P < 0.017$). The telerehabilitation group scores were higher than the telephone group scores at 1 and 3 months after the intervention (the mean were higher than 9.26 and 7.35 respectively), and the difference was significant ($P < 0.05$), as shown in Table 4.

**After Internal Fixation**

There was no significant difference between the baseline FIM scores in the two groups ($P > 0.05$). The FIM scores in the telerehabilitation group were higher than those in the telephone group ($F = 11.448$, $P = 0.003 < 0.05$). The FIM scores in both groups increased with time postoperatively ($F = 345.353$, $P = 0.000 < 0.05$), and the increase in scores in the telerehabilitation group was greater than that in the telephone group ($F = 30.602$, $P = 0.000 < 0.05$). The scores in both groups at 1 and 3 months after the intervention were significant compared to those at pre-intervention ($P < 0.017$). The telerehabilitation group scores were higher than the telephone group scores at 1 and 3 months after the intervention.

**TABLE 2** Comparison of Harris hip scores between the two groups before and after the intervention after hip replacement (mean ± SD)

| Groups                    | Pre-intervention | 1 month after the intervention | 3-month after the intervention |
|---------------------------|------------------|--------------------------------|-------------------------------|
| Telerehabilitation group  | 39.29 ± 6.17     | 56.76 ± 5.13<sup>b</sup>       | 75.41 ± 7.37<sup>b</sup>      |
| (n = 17)                  |                  | 5.13<sup>a</sup>               | 7.37<sup>a</sup>              |
| Telephone group           | 40.93 ± 6.28     | 49.93 ± 7.59<sup>a</sup>       | 67.07 ± 11.04<sup>a</sup>     |
| (n = 14)                  |                  |                                |                               |

Notes: Significance level of paired samples $t$-test $P = 0.05/3 = 0.017$.  
<sup>a</sup>Within-group comparison: compared with pre-intervention, $P < 0.017$;  
<sup>b</sup>Between-group comparison, compared with the control group at the same time point, $P < 0.05$;  
<sup>c</sup>Compared with 1 month after the intervention, $P < 0.017$.

**TABLE 3** Comparison of Harris hip scores between the two groups before and after the intervention after internal fixation (mean ± SD)

| Groups                    | Pre-intervention | 1 month after the intervention | 3-month after the intervention |
|---------------------------|------------------|--------------------------------|-------------------------------|
| Telerehabilitation group  | 37.40 ± 6.48     | 47.90 ± 5.17<sup>b</sup>       | 64.40 ± 6.80<sup>b</sup>      |
| (n = 10)                  |                  | 5.17<sup>a</sup>               | 8.00<sup>a</sup>               |
| Telephone group           | 34.90 ± 5.72     | 40.70 ± 5.62<sup>a</sup>       | 52.80 ± 7.45<sup>a</sup>      |
| (n = 10)                  |                  |                                |                               |

Notes: Significance level of paired samples $t$-test $P = 0.05/3 = 0.017$.  
<sup>a</sup>Within-group comparison: compared with pre-intervention, $P < 0.017$;  
<sup>b</sup>Between-group comparison, compared with the control group at the same time point, $P < 0.05$;  
<sup>c</sup>Compared with 1 month after the intervention, $P < 0.017$.

**TABLE 4** Comparison of FIM scores between the two groups before and after the intervention after hip replacement (mean ± SD)

| Groups                    | Pre-intervention | 1 month after the intervention | 3-month after the intervention |
|---------------------------|------------------|--------------------------------|-------------------------------|
| Telerehabilitation group  | 63.82 ± 3.09     | 91.47 ± 4.16<sup>b</sup>       | 108.35 ± 4.53<sup>b</sup>     |
| (n = 17)                  |                  | 4.16<sup>a</sup>               | 7.20<sup>a</sup>              |
| Telephone group           | 63.29 ± 2.52     | 82.21 ± 5.83<sup>a</sup>       | 101.00 ± 7.15<sup>a</sup>     |
| (n = 14)                  |                  |                                |                               |

Notes: Significance level of paired samples $t$-test $P = 0.05/3 = 0.017$.  
<sup>a</sup>Within-group comparison: compared with pre-intervention, $P < 0.017$;  
<sup>b</sup>Between-group comparison, compared with the control group at the same time point, $P < 0.05$;  
<sup>c</sup>Compared with 1 month after the intervention, $P < 0.017$.

**TABLE 5** Comparison of FIM scores between the two groups before and after the intervention after internal fixation (mean ± SD)

| Groups                    | Pre-intervention | 1 month after the intervention | 3-month after the intervention |
|---------------------------|------------------|--------------------------------|-------------------------------|
| Telerehabilitation group  | 60.30 ± 2.91     | 81.70 ± 5.08<sup>b</sup>       | 98.70 ± 5.33<sup>b</sup>      |
| (n = 10)                  |                  | 5.08<sup>a</sup>               | 7.20<sup>a</sup>              |
| Telephone group           | 62.00 ± 3.16     | 72.20 ± 3.08<sup>a</sup>       | 91.40 ± 5.56<sup>a</sup>      |
| (n = 10)                  |                  |                                |                               |

Notes: Significance level of paired samples $t$-test $P = 0.05/3 = 0.017$.  
<sup>a</sup>Within-group comparison: compared with pre-intervention, $P < 0.017$;  
<sup>b</sup>Between-group comparison, compared with the control group at the same time point, $P < 0.05$;  
<sup>c</sup>Compared with 1 month after the intervention, $P < 0.017$.  

**Table 6** Comparison of FIM scores between the two groups before and after the intervention after internal fixation (mean ± SD)

| Groups                    | Pre-intervention | 1 month after the intervention | 3-month after the intervention |
|---------------------------|------------------|--------------------------------|-------------------------------|
| Telerehabilitation group  |                 |                                |                               |
| (n = 17)                  |                  |                                |                               |
| Telephone group           |                 |                                |                               |
| (n = 14)                  |                  |                                |                               |
intervention (the mean were higher than 9.50 and 7.30 respectively), and the difference was significant ($P < 0.05$), as shown in Table 5.

**Comparison of Somatic Integrative Ability between the Two Groups after Hip Replacement**

After 3 months of the intervention, the telerehabilitation group took shorter time for TUG than the telephone group ($D = 6.92$) and had higher SPPB scores than the telephone group ($D = 1.23$), and the differences were significant ($P < 0.05$), as shown in Table 6.

**Discussion**

Our affiliation has launched a special green channel for rapid surgery within 48 h in the hip ward with 72 beds in accordance with the international standard guidelines set by the AAOS to actively promote surgery and accelerate post-operative rehabilitation for elderly hip fracture patients. According to the statistics, the volume of hip fracture surgery in our affiliation last year was more than 2000 cases, and the average postoperative hospital stay was 4–5 days. Home rehabilitation is an important option post-hospital discharge for hip fracture, and home-based tele-rehabilitation is increasingly welcomed by patients. In this study, we found that patients using the mobile app for the home programme showed slightly better improvement in the outcomes (HHS, FIM, TUG and SPPB) than those who received telephone follow-up.

**The Effect of Home-based Telerehabilitation on the Recovery of Hip Function**

The results of this study showed that no matter after hip replacement or internal fixation, the HHS scores in both groups gradually improved over time, indicating that the hip function in both groups gradually recovered over the prolonged postoperative period. The scores in the telerehabilitation group at 1 and 3 months after the intervention were significantly higher than those in the group, and the difference was significant ($P < 0.05$), which indicates that the use of the “rehabilitation management system” for remote rehabilitation can improve the hip function and is better than the effect of traditional telephone follow-up, which supports the results of previous studies. Yang et al. used a mobile application to provide rehabilitation training videos for post-operative hip replacement patients, with regular return visits to understand the rehabilitation effect and timely adjustment of the training plan, which eventually led to positive findings. But their app does not seem to be able to perform real-time video, and has some limitations. Elderly patients or family members have difficulty in communicating via telephone, and they may not understand or remember the physician’s instructions, resulting in irregular rehabilitation training movements and low compliance with rehabilitation. All these factors can affect the functional recovery outcome of patients. The patients in the telerehabilitation group were discharged from the hospital to conduct rehabilitation training at home according to the personalized rehabilitation program and rehabilitation video delivered by the system and to receive regular remote assessment and guidance. This type of home rehabilitation can visually observe the degree of functional recovery of the patients, which is more convenient for communication and more advantageous for personalized guidance. Patients and their family members can check the rehabilitation information at any time through the patient APP, which not only prevents forgetfulness in elderly patients, but also facilitates motivation and initiative for rehabilitation. Kallron et al. concluded that compared with paper-based rehabilitation exercise manuals, video materials are more vivid and easy to understand and master, which increases the attractiveness of rehabilitation training. In addition, family support is an important part of postoperative rehabilitation. The “rehabilitation management system” for home rehabilitation requires the family and the patient to jointly schedule consultations and participate in remote assessment and guidance. The patient APP also has a warm reminder function, and patients can set their own reminder time for rehabilitation training to enhance self-monitoring and management, which facilitates long-term adherence. Finally, different compliance rates might explain the greater benefits in the telerehabilitation group.

**The Effect of Home-based Telerehabilitation on the Ability to Perform Activities of Daily Living**

The recovery rate of hip fractures is low, even in patients with a high level of pre-fracture function, and the prognosis is worse in patients who are older and have impaired cognition and multiple coexisting medical conditions. The results of this study showed no matter after hip replacement or internal fixation, a gradual improvement in FIM scores, i.e., a gradual improvement in the ability to perform activities of daily living, in both groups as the postoperative time increased. The FIM scores of patients in the telerehabilitation group were significantly higher than those of patients in the telephone group at 1 and 3 months after the intervention with a significant difference ($P < 0.05$), indicating that remote home rehabilitation using the “rehabilitation management system” can effectively improve patients’ activities of daily living. This is consistent with the results presented by Wang et al., who used an Internet home care platform to provide rehabilitation care guidance for patients after hip

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**TABLE 6** Comparison of somatic integrative abilities between the two groups after hip replacement at 3-month after surgery

|                  | TUG (mean ± SD) | SPPB (mean ± SD) |
|------------------|-----------------|------------------|
| **Telerehabilitation group (n = 17)** | 18.36 ± 3.83 | 5.94 ± 0.39 |
| **Telephone group (n = 14)** | 25.28 ± 6.90 | 4.71 ± 0.37 |
| **t** | –3.345 | 2.257 |
| **p** | 0.003* | 0.032** |

Note: Comparison between groups, * $P < 0.01$, ** $P < 0.05$. 

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replacement, and the results showed that the platform fulfilled the rehabilitation needs and expectations of the general patient population and effectively improved patients’ daily activities. In the present study, patients were encouraged to complete activities of daily living independently within the safety limits. Patients were instructed to get in and out of bed, dress and undress, and perform toileting, transferring and walking correctly, and their family members were advised to purchase assistive devices such as walkers, long-handle graspers, and sock dressers and make modifications to the home environment to improve patients’ ability to take care of themselves. During the study, it was found that most of the patients still believed the conservative idea of “more rest and less exercise after fractures” and were apprehensive or did not pay attention to early rehabilitation exercises due to the fear of falling again. Through the “rehabilitation management system,” patients’ confidence and determination to achieve recovery were boosted by regular delivery of rehabilitation information and remote interactive communication; thus, establishing a trusted doctor-patient relationship, instilling correct rehabilitation concepts, and providing psychological rehabilitation services whenever necessary.

The Effect of Home-based Telerehabilitation on the Somatic Integrative Ability
Balance impairment, and postural and gait abnormalities are common problems faced by hip fracture patients, limiting their daily activities and creating a sense of physical insecurity, thus increasing the risk of falls. This study assessed the somatic integration ability of patients after hip replacement at 3 months after surgery. The results of this study showed that the TUG test results of the telerehabilitation group were better than those of the telephone group, and had a lower risk of falls. This is consistent with the findings presented by Kalron et al. who used an application to implement a telerehabilitation intervention for elderly post-operative hip fracture patients and concluded that this intervention had a positive impact on patients’ walking ability. As noted, there are advantages and disadvantages to each telerehabilitation system. Therefore, the analysis of research results should take into account the specific platform. Veronese et al. investigated the association between SPPB scores and fall risk and concluded that a score of ≤6 was associated with a higher risk of falls. However, in the present study the mean SPPB scores in the telerehabilitation group and the telephone group were 5.94 and 4.71, respectively, but the difference between the two groups was significant ($P < 0.05$). This indicates that patients in both groups had a higher risk of falls in the future, but patients in the telephone group had a significantly higher risk of falls than those in the telerehabilitation group. By combining the results of the above two tests, it can be concluded that Internet telerehabilitation can improve patients’ somatic integrative ability and can reduce the risk of falls to a certain extent. We provide the following explanation for this finding.

In most cases, falls are caused by the loss of balance during walking (dynamic balance) or the inability to maintain the body’s center of gravity on a support surface (static balance). Balance is a comprehensive function that requires the joint participation of motor and sensory components. Most elderly patients have accompanying chronic diseases, decreased motor function, decreased proprioception, and vestibular dysfunction. Therefore, joint enhancement of plyometrics, balance, and proprioceptive training may lead to effective improvement of balance function. Patients in the telerehabilitation group performed functional exercises under the guidance of the rehabilitation program and videos, starting with weight shifting in the standing position, using a walker to assist with walking exercises in the early stage, and gradually reducing the assistance to achieve independent walking. In addition, it was found that most of the patients had various gait problems as their body weight was shifted to the affected side. The patients were allowed to walk at their natural gait speed from frontal, lateral, and rear views via a remote video, and their gait was individually assessed to identify possible problems and provide individualized guidance. It is worth mentioning that the system can remotely monitor the vital signs of patients, which is more conducive to scientifically adjust the rehabilitation program. The “rehabilitation management system” optimizes the access to rehabilitation resources and allows the patients to receive rehabilitation treatment through multiple channels, which is more conducive to improving their somatic integration. Li et al. concluded that remote home rehabilitation was effective in improving patients’ self-care abilities, but it had no significant advantage in improving the gait speed, balance, and quadriceps strength. This may be due to the different remote rehabilitation techniques, research methods, rehabilitation protocols, and exercise intensities used in the two studies.

The Effect of Home-based Telerehabilitation on the Mortality
The results of this study showed that none of the 51 patients died within 3 months, and a total of three died within 1 year after surgery, with a 1-year mortality of 5.88% (3/51) (less than that reported in previous studies). One patient died in the telerehabilitation group with a mortality of 3.70% (1/27), and two patients died in the telephone group with 8.33% (2/24). According to the Fisher’s exact probability test, there was no significant difference between the two groups ($P = 0.595 > 0.05$). Factors associated with mortality were age, gender, comorbidities, type of fracture, timing of surgery and rehabilitation, etc. In addition, the sample size of this study was relatively small, and those patients with severe comorbidities were excluded, possibly leading to some bias in the results. Therefore, further studies are needed to explore the effects of remote rehabilitation on postoperative mortality.
hip joint and enhance the ability to perform activities of daily living and somatic integration to a certain extent. In addition, the system is simple to operate and easy to use. For medical workers, the system facilitates the management of basic information and rehabilitation data, and can effectively track the rehabilitation process of patients to achieve personalized rehabilitation treatment. The system can also automatically deliver rehabilitation videos according to the patient’s condition, which can reduce the clinical workload to a certain extent. This seems to provide an effective option for conducting home rehabilitation and an important tool for preventing or reducing aggregation under the normalized prevention and control of the new COVID-19 pneumonia epidemic.

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