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ORIGINAL RESEARCH

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Progressive balance training program for total hip arthroplasty patients using behavior change wheel theory

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Abstract

Femoral neck fractures are a common type of fracture, accounting for approximately 3.58% of total body fractures and about 50% of proximal femoral fractures. They are particularly prevalent in elderly individuals with osteoporosis, especially those aged 65 and older. This study aims to develop and implement a progressive balance training program for elderly femoral neck fracture patients, guided by the behavior change wheel theory. Through literature review and expert consultation, we developed a progressive balance training program using the behavior change wheel theory. We selected 83 patients admitted to our orthopedics department for hip surgery between January 2022 and December 2022 and divided them into a control group (n = 42) and an intervention group (n = 41). The control group followed a standard exercise program, while the intervention group underwent the progressive balance training program. Their rehabilitation outcomes were compared using the Berg Balance Scale, Harris hip joint function assessment, and the Chinese version of the Fall Efficiency Scale at the first bedside standing, as well as at 2 weeks, 6 weeks and 12 weeks after the operation. Repeated measures analysis of variance revealed statistically significant time-related effects, interaction effects and between-group effects in both groups for the Berg Balance Scale scores (F_{time} = 5753.969, $F_{interaction}$ = 221.20, $F_{between-groups}$ = 1496.285), Harris hip joint function scores (F_{time} = 2750.864, $F_{interaction}$ = 115.315, $F_{between-groups}$ = 760.690), and Fall Efficiency Scale scores (F_{time} = 2590.021, $F_{interaction}$ = 176.961, $F_{between-groups}$ = 625.033) postoperatively. We conclude that the progressive balance training program developed based on the behavior change wheel theory can accelerate the postoperative balance recovery in total hip arthroplasty patients, promote hip joint function recovery, and reduce the fear of falling among patients.

Keywords

Total hip replacement; Men; Behavioral change theory; Progressive training; Rehabilitation care

1. Introduction

Hip arthroplasty is a common type of fracture, comprising approximately 3.58% of systemic fractures and accounting for around 50% of proximal femur fractures [1]. This procedure is prevalent among elderly individuals with osteoporosis, particularly those aged 65 and older [2]. Common treatments for hip arthroplasty patients include artificial femoral head replacement and total hip replacement, both aimed at stabilizing the fracture and restoring hip function [3]. Encouraging early mobility following artificial joint replacement helps mitigate complications such as infection, thrombosis and surgical failure associated with prolonged bed rest [4].

In the postoperative recovery of elderly hip arthroplasty patients, challenges often include slow functional recovery, limitations in activity, and significant psychological stress, leading to mood fluctuations. The Behavior Change Wheel (BCW) theory [5] serves as a theoretical framework for understanding and designing behavioral change interventions. It helps researchers and practitioners in systematically comprehending and developing strategies to modify individual behavior, is valuable for healthcare professionals in crafting rehabilitation programs that address patient needs comprehensively, and enables the delivery of increased rehabilitation education, emotional support, and enhanced patient awareness and motivation [6]. The BCW hypothesis allows medical personnel to focus their efforts on encouraging patient participation in rehabilitation, thus improving rehabilitation outcomes and enhancing patient satisfaction [7].

This study aims to establish a progressive balance training program for elderly patients who have undergone total hip replacement.

2. Construction of progressive balance training program for total hip arthroplasty patients

2.1 Formation of fracture balance training research team

The fracture balance training research team consisted of several key members: one orthopedic head nurse, one orthopedic physician, one rehabilitation therapist, two orthopedic nurses, and one orthopedic specialist nurse. The head nurse was responsible for overall program coordination, ensuring smooth operations and effective information exchange. The orthopedic surgeon conducted comprehensive health assessments and evaluated rehabilitation potential, providing medical guidance and monitoring rehabilitation progress. Rehabilitation therapists assessed muscle strength, balance and individual rehabilitation needs, devising personalized training plans and overseeing adjustments during training. The two nurses provided daily and discharge care to ensure patient well-being. The orthopedic nurses conducted literature searches, quality analysis and data collection. Under the head nurse's leadership, the team initiated the development of the Total hip arthroplasty (THA) Progressive Balance Training Program, which involved two rounds of expert consultations, resulting in the final version of the THA Progressive Balance Training Program, which was subsequently implemented.

2.2 Literature search

We conducted a comprehensive literature search across multiple databases, including China Knowledge Network (CNKI), Wanfang database, Wipro database, PubMed database, Scopus database and Web of Science database, to identify related studies published from 2019 to 2023 using the search terms "elderly", "femoral neck fracture", "balance exercise", "behavior change wheel theory", "progressive training" and "rehabilitation". Additionally, we utilized variations such as "geriatric", "hip arthroplasty", "balance training" and "progressive training" to refine the search. We selected domestic journal articles and dissertations on balance training for elderly femoral neck fracture patients, with an emphasis on the BCW theory and progressive training. Following this comprehensive search, we identified and screened 10 high-quality pieces of literature, based on which we drafted the initial version of the balance training program based on a synthesis of the behavior change theory and insights gained from interviews with orthopedic specialists and rehabilitation therapy experts at our institution.

2.3 Expert correspondence

2.3.1 Design of expert questionnaire

The study expert questionnaire mainly included ① Letter to Experts, which included the purpose of the study, research methods, instructions for completing the questionnaire, and more; ② Main body of the questionnaire, which comprises the detailed indicators at all levels, along with their importance ratings on a Likert 5-level scale, ranging from "very insignificant" (1 point) to "very important" (5 points). Experts were also invited to provide additional comments and suggest revisions in a dedicated remarks column; ③ Basic Information Sheet for Experts, which collected general information about the experts, along with a self-assessment of their familiarity with the questionnaire's content and the rationale behind their judgments.

2.3.2 Selection of correspondence experts

Delphi correspondence experts were required to possess expertise in relevant medical fields, including rehabilitation medicine, and hold the status of medical professionals or researchers to ensure their substantial experience and comprehensive knowledge in fracture rehabilitation. The inclusion criteria were as follows: ① Had a Bachelor's degree or higher and an intermediate or advanced professional title; ② Specialization in clinical nursing, nursing management, rehabilitation exercise, or clinical medical care with specific work experience related to bone and joint health; ③ Accumulated professional experience exceeding 10 years; and ④ Willingness to voluntarily participate in this study and engage in 2 rounds of expert correspondence within the research timeframe.

2.3.3 Implementation of expert correspondence

Two rounds of email consultations were conducted, each lasting 2 weeks. The progressive balance training program was refined based on feedback from the initial round of expert consultations and through discussions within the research team. After considering the input and recommendations from the second round of expert consultations, further enhancements were made to the intervention program. To assess the program's feasibility and effectiveness, a preliminary implementation was conducted with ten selected patients. During this phase, patient feedback was collected to make necessary revisions and finalize the intervention program. The specific details of the progressive balance training program can be found in Table 1.

3. Application of progressive balance training program based on BCW theory

3.1 Research data

In this study, a total of 83 male patients admitted to the orthopedic department of our hospital for hip surgery between January 2022 and December 2022 were included. They were conveniently selected and randomly divided into two groups: the control group (n = 42) and the intervention group (n = 41). The intervention group received a progressive balance training program based on the BCW theory, while the control group followed a traditional exercise regimen.

The inclusion criteria for the study were as follows: patients aged 65 years or older, first-time unilateral hip replacement treatment, stable physical condition after surgical treatment without serious comorbidities, positive willingness to participate in the progressive balance training program, and absence of significant cardiac or pulmonary diseases or other conditions limiting mobility.

TABLE 1. Rehabilitation training programs.

Stage	Balance training interventions	Frequency	Significance
Early postoperative period (1–2 weeks)	1. Bed rehabilitation involves limb movement and passive joint exercises to alleviate pressure on the injured leg, which includes (1) Hip flexion exercises: Establish a trusting nurse-patient relationship and instruct the patient to flex their knee joint. Conduct heel sliding exercises towards the hip, with hip flexion not exceeding 70°, and (2) Prone hip abduction training: The patient lies in the supine position and performs hip abduction with the affected leg, ranging from 10° to 30°. Contraction exercises targeting the corresponding muscle groups are also performed.	15–20 times/group, 3 times/day	
	2. Wheelchair activities involve conducting sitting training and assisting patients in transferring from the bed to the wheelchair. Additionally, moderate wheelchair activities are performed to facilitate patient rehabilitation.	10–15 times/group, 3 times/day	Increases joint mobility
	3. Breathing exercises encompass deep breathing and coughing exercises, which serve to prevent respiratory tract infections.	3–5 min/times, 3times/day	Increases lung capacity and reduces lung infections
Mid postoperative period (3–6 weeks)	1. Walking exercises include a gradual transition from relying on a wheelchair to utilizing walking aids, such as crutches or walking frames.	10–15 times/group, 3 times/day	Increases joint balance
	2. Balance training involves performing standing balance and single-leg balance exercises to enhance muscle control in the affected leg, which includes: (1) Standing hip abduction/extension training: The patient stands supported against a wall or with the assistance of family members. They maintain hip stability, keep the abdomen closed, and avoid twisting the body. (2) Toe/heel lift training: While in a standing position, with hands on a walker, eyes facing forward, and feet shoulder-width apart, the patient attempts to lift the heel, directing the toes toward the ground. After holding this position for 10 seconds, they return to the original position and then attempt to lift the toes so that the two heels point to the ground.	15–20 min/times, 3 times/day	Increases joint balance and prevents muscle atrophy and joint stiffness
Postoperative period (7–12 weeks)	1. Intensive rehabilitation training focuses on enhancing strength, targeting both leg muscles and core muscles and includes: (1) Knee bending and half-squatting exercises: The patient stands with legs apart at shoulder width and gradually practices squatting. (2) Single-leg stand on the healthy limb: Using a standing aid, the patient raises the operated leg off the ground and attempts to balance without support. Each exercise lasts for 10 seconds, and during the initial attempts, family supervision is recommended to prevent falls. Patients are instructed to hold onto the aids and cease the exercise immediately if they experience any discomfort or imbalance.	5 times/group, 3 times/day	Increases joint balance
	2. Walking exercises are crucial for improving gait stability. These exercises involve: (1) Walking: Patients are instructed to walk along the ward corridor or a designated straight-line area at home, covering a distance of 5 meters initially, with a goal of gradually increasing the distance to 10–30 meters. Patients are encouraged to maintain proper direction, adhere to the training regimen, and perform standardized movements. (2) Toe/heel walking training: Patients are guided to walk with an upright posture, initially using their toes and then transitioning to heel walking. This process is alternated between toe and heel walking. (3) Figure-eight walking training: Patients use a hand walker to walk in a clockwise direction from a specified point at a normal pace. They then return to the starting point and walk in a counterclockwise direction, following a figure-eight pattern.	15–20 min/times, 3 times/day	Increases muscular endurance and strength
	3. Functional training involves simulating daily life movements to enhance patients' abilities in activities such as walking up and down stairs and performing sitting-to-standing transfers, which are essential for improving overall functionality and daily life independence.	20–30 min/times, 3 times/day	Increases the function of the affected limb and the patient's ability to take care of himself/herself

Exclusion criteria included pathological proximal femoral fractures (with a duration of more than 3 weeks), clinical diagnosis of other types of fractures, severe heart or lung diseases, lack of willingness to participate or cooperate with the training program, previous participation in other balance training or rehabilitation programs, and severe cognitive dysfunction or mental illness. The study was approved by the Ethics Committee of our hospital, and the general characteristics of the two groups are summarized in Table 2.

TABLE 2. Comparison of the general data of the two groups.

Variables	Intervention group (n = 41)	Control group (n = 42)	χ^2/t	p
Age (yr)	72.98 ± 5.02	71.57 ± 6.39	1.112	0.270
Days of hospitalization	19.83 ± 12.20	12.81 ± 6.75	0.745	0.456
Marital status				
Married	31 (75.6%)	29 (69%)	0.446	0.504
Divorced/ widowed	10 (24.4%)	13 (31%)		
Comorbidity				
Yes	14 (34.1%)	17 (40.5%)	0.355	0.551
No	27 (65.9%)	25 (59.5%)		

3.2 Research methods

3.2.1 Research methods of the intervention group

The progressive balance training program described in Table 1 was implemented as the intervention in this study. Prior to the intervention, the research team received standardized training on the BCW, the progressive balance training program, and related knowledge, conducted by a rehabilitation therapist. Individualized interventions were then given to patients based on their specific condition and self-care capabilities. Throughout the intervention period, the rehabilitation therapist and head nurse provided supervision and guidance to patients. Face-to-face interventions were conducted during hospitalization, while telephone or WeChat interventions were utilized after discharge. The intervention continued for 3 months, and the detailed measures are outlined in Table 3.

3.2.2 Research methods of the control group

The control group received conventional care for hip replacement patients, which included assisting elderly patients with bed position changes post-surgery to prevent prolonged immobility and the development of pressure sores. A professional rehabilitator conducted physical therapy, which comprised muscle exercises, joint mobility training, and rehabilitation exercises aimed at enhancing strength and flexibility. Under the guidance of physicians and rehabilitators, patients gradually initiated walking training, potentially with the assistance of mobility aids like walkers. Patients were advised to:

• Maintain a balanced diet with sufficient protein and nutrients and follow prescribed calcium and vitamin D supplementation to support wound healing and the rehabilitation process.

• During the recovery period, avoid falls and pay attention to the safety in their surroundings, such as laying non-slip carpets and using handrails.

• Adhere to their physician's recommendations and attend regular follow-up appointments to monitor recovery progress and ensure proper healing of the fracture site.

Postoperative rehabilitation care was individualized to suit the unique condition of each patient. To promote rapid recovery and the restoration of function, patients and their families were encouraged to work closely with the healthcare team. Furthermore, telephone follow-up sessions were scheduled throughout the 3-month intervention period following hospital discharge.

3.3 Evaluation indicators

3.3.1 Berg balance scale

Berg Balance Scale is a widely employed assessment method for evaluating balance ability, which was initially introduced by Berg *et al.* [8] in 1989. It comprises 14 performance tasks, all of which center on assessing balance. The scale has demonstrated high reliability, with reported coefficients of 0.97 and 0.95. Scores on the scale range from 0 to 56 points, with a score of 20 indicating poor balance, necessitating the use of a wheelchair for mobility. Scores between 21 and 40 suggest moderate balance, allowing for the use of a walker or cane to support safe walking, while scores between 41 and 56 indicate good balance, enabling independent walking.

3.3.2 Harris hip function scale

The Harris Hip Function Scale [9] was employed to assess patients' hip function, encompassing dimensions of pain, deformity, function and mobility, with a total score of 100 points. A higher score indicates better hip function recovery.

3.3.3 Fall efficacy

Fall efficacy was assessed using the Modified Falls Efficacy Scale (MFES) [10], which consists of two dimensions and 14 items, categorized into indoor activities (9 items) and outdoor activities (5 items). It measures the confidence of older adults in their ability to prevent falls and has been validated for reliability and validity.

3.4 Data collection

Data collection was conducted by orthopedic specialist nurses proficient in the assessment method. Patient information was collected before the intervention, and assessments for balance, hip function, and fall risk were performed at the initial bedside standing, as well as at 2 weeks, 6 weeks and 12 weeks post-surgery.

TABLE 3. Rehabilitation program for total hip arthroplasty patients based on BCW theory.

Intervention Goals	Intervention function	Balance training content	Forms of intervention
Formation of motivation	Stimulates intrinsic motivation	Show successful cases to stimulate patients' internal motivation for self-improvement and emphasize exercise's role in health restoration and independent living.	Face to Face, 20–30 min
	Setting clear goals	① Provide educational materials on progressive balance training and rehabilitation to help patients understand the content of the training and the expected results. ② Work with patients to develop personalized rehabilitation goals, clarify the purpose and meaning of exercise, and make them understand the close relationship between exercise and rehabilitation.	
	Rewarding a sense of accomplishment	Establish a reward mechanism for exercise achievement, recognizing and rewarding patient progress regularly to boost motivation.	
Acquiring competencies	Educate and inform	Provide comprehensive information about functional exercises to patients and their families, emphasizing the advantages of exercise in enhancing physical capabilities and enhancing overall quality of life. This approach aims to augment patients' knowledge and comprehension of balance training.	Face to Face, 20–30 min
	Developing a personalized recovery plan	① Develop a personalized functional exercise plan according to the patient's age, health status, fracture type and rehabilitation goals. ② Develop a detailed progressive balance training program, including specific training movements, training duration, frequency and target progress. ③ Assist the patient in preparing rehabilitation equipment, such as the balance board, stabilization ball and single crutch.	
	Psychological support and encouragement	① Provide patients with positive psychological support and encouragement to help them maintain a positive attitude toward rehabilitation. ② Encourage patients to continue exercising and overcome difficulties and challenges in the rehabilitation process. ③ Encourage family members to provide support and encouragement during the rehabilitation process and participate in the patient's functional exercises together.	
Creating opportunities	Family involvement and social support	① Encourage family members to provide support and encouragement during the rehabilitation process and participate in the patient's functional exercise together. ② Utilize community resources to provide necessary support, such as rehabilitation aids and rehabilitation social activities, to attract more elderly patients with hip arthroplasty to participate and increase exercise opportunities. ③ Organize regular rehabilitation courses, including functional exercises and rehabilitation education, in collaboration with the hospital community so that elderly patients can continue exercising to enhance their strength and function.	Online + Offline
	Home exercise instruction	① Provide guidance on functional exercises to the patient's family members and help them perform appropriate exercises at home to promote the progress of rehabilitation. ② Use assistive devices such as balance boards and balance balls to elevate the level of exercise difficulty, thereby enhancing patients' balance. Additionally, provide walking aids, hand canes, and other supportive equipment to ensure the safety and stability of patients during their exercise routines.	
	Records and feedback	Motivate patients to document their exercise routines and achievements and offer ongoing feedback and assessments for them to observe and appreciate the beneficial impacts and transformations of their exercise.	

3.5 Statistical methods

Statistical analysis was performed using SPSS 25.0 (IBM Corporation, Armonk, NY, USA), with data entered and checked by two individuals. Normally distributed measurement data were presented as mean ± standard deviation and analyzed using *t*-tests or Repeated measurement variance analysis. Count data were expressed as frequencies and percentages, and group comparisons were conducted using the χ^2 test. A significance level of $p < 0.05$ was considered statistically significant.

4. Results

4.1 Comparison of Berg Balance Scale scores at different time points between the two groups

Repeated measures of variance analysis (ANOVA) applied to the Berg Balance Scale scores revealed significant differences ($p < 0.05$) both within and between the groups, as well as interaction effects post-intervention (Table 4). When comparing the Berg Balance Scale scores of patients at different time points (2 weeks, 6 weeks and 12 weeks after surgery), the intervention group demonstrated significantly higher scores than the control group, with a statistically significant difference ($p < 0.05$).

4.2 Comparison of hip joint function recovery at different time points between the two groups

Statistical significance ($p < 0.05$) was observed in the comparisons between groups, within groups, and interaction effects following the intervention, as determined by ANOVA applied to the hip function scores (Table 5). The recovery of hip joint function at different time points (2 weeks, 6 weeks and 12 weeks after surgery) was also statistically significant ($p < 0.05$), with the intervention group achieving higher scores than the control group.

4.3 Comparison of the Chinese version of the Falls Efficacy Scale scores at each time point between the two groups

Statistical significance ($p < 0.05$) was observed in the comparisons between groups, within groups, and interaction effects following the intervention, as determined by ANOVA applied to the fall efficacy scores (Table 6). When comparing fall efficacy scores at two weeks, six weeks, and twelve weeks after surgery, it was found that the intervention group scored significantly higher than the control group, and this difference was statistically significant ($p < 0.05$).

5. Discussion

5.1 Progressive balance training can effectively improve the balance of total hip replacement patients

Progressive balance training plays a pivotal role in post-hip replacement interventions across various stages, progressively enhancing patients' balance capabilities by intensifying training difficulty [11]. ANOVA indicated that the Berg Balance Scale scores exhibited significant time effects, interaction effects, and between-group effects in the postoperative period for both patient groups ($p < 0.05$) ($F_{time} = 5753.969$, $F_{interaction} = 221.20$, $F_{between-group} = 1496.285$), indicating that patients in the intervention group had superior balance abilities compared to those in the control group, which can be attributed to the benefits of progressive balance training, such as preventing soft tissue adhesions around the hip joint and facilitating venous return [12, 13]. As rehabilitation progresses, patients transition from wheelchair reliance to supportive walking exercises and eventually to walking exercises, all of which contribute to the restoration of normal gait and improved balance [14]. During the mid-postoperative phase, the focus of balance training shifts towards enhancing joint balance and reinforcing muscle control in the affected leg through standing balance and single-leg balance exercises, aligning with the findings of Holsgaard-Larsen A [15]. These exercises effectively prevent muscle atrophy and joint stiffness while promoting muscle strength and control. Taken together, progressive balance training enhances the balance of hip replacement patients through systematic rehabilitation interventions and the gradual escalation of training complexity [16]. Emphasizing muscle strength, neural adaptation, reaction time, and self-confidence at different rehabilitation stages allows patients to adapt progressively to diverse balance challenges, ultimately achieving functional recovery and enhancement [17].

5.2 Progressive balance training can effectively promote the recovery of hip joint function in total hip replacement patients

Progressive training methods, characterized by a progression from simplicity to complexity and from low to high difficulty levels, facilitate patients' gradual adaptation and enhancement of muscle strength, balance perception, and coordination abilities [18]. The results of ANOVA demonstrated significant time effects, interaction effects, and between-group effects for hip function scores in both patient groups after surgery ($p < 0.05$) ($F_{time} = 2750.864$, $F_{interaction} = 115.315$, $F_{between-groups} = 760.690$). Progressive balance training encompasses a wide range of exercises, including various hip movements such as flexion, extension, abduction and posterior extension, as well as diverse balance training activities such as standing balance, single-leg balance and walking exercises. This comprehensive training regimen is designed to actively involve and stimulate the muscles around the patient's hip joint to promote joint mobility restoration and muscle strength enhancement [19]. Progressive balance training stimulates the patient's nervous system and fosters the development of neuroadaptive capabilities by incrementally increasing the level of difficulty, as seen in single-leg balance and walking exercises [20]. This is crucial for reestablishing the hip joint's normal movement patterns, enhancing balance stability, and enabling patients to manage various balance challenges, aligning with Madara K C's findings [21], which highlighted that progressive balance training improved patients' muscular coordination, boosted the synergy among muscle groups necessary for support and

TABLE 4. Comparison of Berg Balance Scale scores at different time points between the two groups (score, $\bar{x} \pm s$).

Grouping	Number of cases	First bedside standing	2 weeks after surgery	6 weeks after surgery	12 weeks after surgery	F_{time}	$F_{interaction}$	$F_{between-group}$
Intervention group	41	17.46 ± 1.28	33.59 ± 0.80$^{(1)}$	46.95 ± 1.72$^{(1)}$	49.29 ± 2.40$^{(1)}$	5753.969$^{(2)}$	221.200$^{(2)}$	1496.285$^{(2)}$
Control group	42	17.67 ± 1.26	25.38 ± 1.68$^{(1)}$	35.60 ± 1.31$^{(1)}$	41.55 ± 2.31$^{(1)}$			
t		−0.738	28.239	33.950	18.304			
p		0.463	<0.001	<0.001	<0.001			

$^{(1)}p < 0.05$ *compared with pre-intervention;* $^{(2)}p < 0.01$.

TABLE 5. Comparison of hip joint function recovery at different time points between the two groups (score, $\bar{x} \pm s$).

Grouping	Number of cases	First bedside standing	2 weeks after surgery	6 weeks after surgery	12 weeks after surgery	F_{time}	$F_{interaction}$	$F_{between-group}$
Intervention group	41	45.88 ± 1.79	56.32 ± 1.92$^{(1)}$	69.34 ± 1.87$^{(1)}$	80.22 ± 2.74$^{(1)}$	2750.864$^{(2)}$	115.315$^{(2)}$	760.690$^{(2)}$
Control group	42	45.19 ± 2.35	50.45 ± 2.44$^{(1)}$	60.05 ± 2.12$^{(1)}$	67.27 ± 2.31$^{(1)}$			
t		1.495	12.154	21.195	22.753			
p		0.138	<0.001	<0.001	<0.001			

$^{(1)}p < 0.05$ *compared with pre-intervention;* $^{(2)}p < 0.01$.

TABLE 6. Intergroup comparison of fall efficacy scores of patients in the two groups (score, $\bar{x} \pm s$).

Grouping	Number of cases	First bedside standing	2 weeks after surgery	6 weeks after surgery	12 weeks after surgery	F_{time}	$F_{interaction}$	$F_{between-group}$
Intervention group	41	5.32 ± 0.86	46.95 ± 1.71$^{(1)}$	60.56 ± 2.37$^{(1)}$	86.32 ± 3.47$^{(1)}$	2590.021$^{(2)}$	176.961$^{(2)}$	625.033$^{(2)}$
Control group	42	5.50 ± 0.89	37.62 ± 2.24$^{(1)}$	54.21 ± 2.71$^{(1)}$	77.05 ± 3.99$^{(1)}$			
t		−1.046	21.26	11.353	14.988			
p		0.299	<0.001	<0.001	<0.001			

$^{(1)}p < 0.05$ *compared with pre-intervention;* $^{(2)}p < 0.01$.

balance, and enhanced hip joint stability and function. Thus, progressive balance training contributes to the recovery of hip function in patients, primarily due to its progressive load increase, multidimensional exercise approach, neuroadaptation and stability development, muscle control and coordination, as well as its positive impact on patients' psychological well-being [22].

5.3 Progressive balance training program can effectively reduce the level of fear of falling in total hip replacement patients

A progressive balance training program can enhance patients' balance abilities and self-confidence, ultimately reducing their fear of falling [23]. The results of the repeated measures of variance analysis revealed significant time effects, interaction effects and between-group effects in fall efficacy scores among the two patient groups post-surgery ($p < 0.05$) (F_{time} = 2590.021, $F_{interaction}$ = 176.961, $F_{between-groups}$ = 625.033), which can be attributed to the gradual nature of progressive balance training as it incrementally builds patients' confidence, starting from the early postoperative period with a gradual training regimen that allows them to adapt to various balance exercises in a safe environment. As training progresses, patients develop trust in their ability to maintain balance in different situations [24]. Progressive balance training also emphasizes the establishment of a nurse-patient trust relationship during the training process, encouraging active patient participation and fostering a sense of progress [25]. This positive psychological support and mindset contribute to reducing patients' fear of falling and increasing their willingness to engage in and adhere to training. These findings align with those of Pfeiffer K [26], who noted that progressive balance training improves balance and emphasizes functional recovery in daily activities such as standing and walking. Through these practical exercises, patients can more readily adjust to their daily responsibilities and decrease their fear of falling [27]. In summary, the progressive balance training program effectively reduces the fear of falling in elderly patients with femoral neck

fractures by gradually building confidence, enhancing balance, promoting neurological adaptation and reaction time, providing psychological support, fostering a positive mindset, and emphasizing functional recovery [28].

6. Conclusions

In this study, we developed a progressive balance training program based on the BCW theory, which can effectively improve patients' balance abilities, boost their self-confidence, and reduce their fear of falling. This approach offers a scientifically sound and effective rehabilitation method for enhancing the quality of life of elderly patients who have undergone hip arthroplasty. Nevertheless, some limitations should be acknowledged. First, the study's sample size was relatively small. Second, the follow-up duration was limited, preventing a comprehensive assessment of long-term rehabilitation effects. Additionally, the study did not account for the variability among individuals, such as patients' ages and health statuses, which might affect the program's applicability. To further validate and enhance the utility of the progressive balance training program, future research could involve larger sample sizes, longer follow-up periods, and the consideration of additional individual variability factors.

AVAILABILITY OF DATA AND MATERIALS

The authors declare that all data supporting the findings of this study are available within the paper and any raw data can be obtained from the corresponding author upon request.

AUTHOR CONTRIBUTIONS

JYL—designed the study and carried them out; JYL, XYL, YL, HCL and XL—supervised the data collection, analyzed the data; JYL, XYL, YL, HCL and XL—interpreted the data; XYL, YL, HCL, XL and QL—prepared the manuscript for publication and reviewed the draft of the manuscript. All authors have read and approved the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study protocol was approved by the West China Hospital Ethics Committee (Date/No: 2021/268, Date: 07/01/2021). Written informed consent was obtained from a legally authorized representative for anonymized patient information to be published in this article.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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