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Impact of FMEA-based proactive nursing combined with individualized functional exercise on hip function in patients following hip replacement

Jie Li^{1†}, Yaqiong Cao^{1†}, Kun Zhang¹, Xin Zhuo¹, Yanhong Zhu¹ and Jie Chen^{1*}

Abstract

Objective This study aimed to investigate the impact of failure mode and effects analysis (FMEA)-based proactive nursing combined with individualized functional exercise on hip function in patients undergoing total hip arthroplasty (THA).

Methods This was a prospective, single-center, randomized controlled trial. Using a consecutive sampling approach, 100 patients who underwent THA at the Affiliated Hospital of Xuzhou Medical University between October 2022 and January 2024 were enrolled and randomly assigned (random number table method) to either a control group ($n = 50$) or an intervention group ($n = 50$). The control group received routine nursing plus standard functional exercise, whereas the intervention group received FMEA-based proactive nursing combined with individualized functional training in addition to routine care. Both groups were followed continuously for 3 months. The primary outcome was hip function, assessed using the Harris hip score (HHS) before and after the intervention. Secondary outcomes included the time to first ambulation, pain during ambulation, and length of hospital stay. Psychological status (anxiety and depression) and quality of life were evaluated before and after the intervention using the Self-Rating Anxiety Scale (SAS), Self-Rating Depression Scale (SDS), and the Short Form-36 questionnaire (SF-36). Postoperative complications were recorded, and nursing satisfaction at discharge was assessed using the Newcastle Satisfaction with Nursing Scale (NSNS).

Results After nursing care, HHS in both the control and intervention groups were higher than before care. Post-intervention, the intervention group showed significantly higher scores than the control group in function (34.62 ± 2.97 vs 27.94 ± 2.87), range of motion (3.64 ± 0.63 vs 2.28 ± 0.45), pain (28.98 ± 4.29 vs 23.52 ± 3.83), and deformity (2.78 ± 0.55 vs 2.02 ± 0.25) ($P < 0.05$). Patients in the intervention group ambulated for the first time earlier than those in the control group (29.12 ± 3.29 h vs 42.20 ± 4.16 h), with lower pain scores during activity (4.46 ± 0.86 vs 6.06 ± 1.27) and shorter hospital stays (11.40 ± 1.93 days vs 14.84 ± 2.71 days) ($P < 0.05$). SF-36 scores in both groups improved after nursing care, with the intervention group demonstrating higher post-care scores in physical function (70.92 ± 6.50 vs 60.06 ± 5.88), mental health (67.88 ± 6.17 vs 58.92 ± 5.71), social function (70.92 ± 6.66 vs 62.84 ± 6.11), and bodily pain (67.82 ± 6.68 vs 59.64 ± 5.24) compared with the control group ($P < 0.05$). Anxiety and depression scores (SAS and SDS)

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decreased in both groups after nursing care, with the intervention group showing lower scores than the control group (SAS 39.02 ± 3.66 vs 46.88 ± 4.52 ; SDS 38.98 ± 3.89 vs 49.58 ± 4.05) ($P < 0.05$). The incidence of postoperative complications was lower in the intervention group (6.00%) than in the control group (22.00%) ($P < 0.05$), and nursing satisfaction was higher (98.00 vs 82.00%) ($P < 0.05$).

Conclusion FMEA-based proactive nursing combined with individualized functional exercise accelerates recovery, improves hip function, reduces pain and negative emotions, enhances quality of life, and lowers complication rates while increasing patient satisfaction.

Keywords Arthroplasty, Failure mode and effects analysis model, Proactive nursing, Individualized functional exercise, Hip function, Nursing satisfaction

Introduction

Total hip arthroplasty (THA), also referred to as total hip replacement (THR), is a widely used surgical intervention for the treatment of degenerative or traumatic disorders of the hip joint, such as osteoarthritis, femoral head necrosis, and hip dysplasia. The decision to perform THA is mainly based on the severity of hip damage, the failure of conservative management, and the recommendation of the orthopedic surgeon (Allaith et al. 2023). THA is considered one of the most successful and cost-effective orthopedic procedures worldwide, offering substantial improvements in pain relief, functional recovery, and quality of life (Fernandez-Palomo and Gonzalez-Pola 2023). Nevertheless, the long-term success of THA largely depends on accurate implant positioning and postoperative management (Migliorini et al. 2023). Even with proper surgical techniques, patients remain at risk of postoperative complications such as dislocation, deep vein thrombosis, infection, or delayed functional recovery (Trung et al. 2023). Despite the clinical success of THA, its postoperative management remains challenging. In real-world clinical settings, patients often present with advanced age, multiple comorbidities, and reduced physical reserve, which increase the risk of postoperative complications and delay functional recovery. In addition, conventional routine nursing pathways are mostly experience-based and lack a standardized risk identification and prevention framework, which may result in early potential failures being overlooked.

Failure mode and effects analysis (FMEA) is a systematic, proactive risk-management tool that enables the early identification of potential process failures and their causes and consequences and helps guide targeted preventive strategies (Liu et al. 2020; Anjalee et al. 2021a). In recent years, FMEA has been widely applied in various healthcare settings, including hospital administration, health information systems, and medication safety programs (Liu et al. 2020). A key advantage of the FMEA methodology is its shift from “post-event remediation” to “early prediction and prevention,” and its use has now been mandated for accredited hospitals as part of regular

prospective safety evaluations (Anjalee et al. 2021b). Despite the clinical success of THA, its postoperative management remains challenging. In real-world clinical settings, patients often present with advanced age, multiple comorbidities, and reduced physical reserve, which increase the risk of postoperative complications and delay functional recovery. In addition, conventional routine nursing pathways are mostly experience-based and lack a standardized risk identification and prevention framework, which may result in early potential failures being overlooked.

Although the majority of patients achieve pain relief after THA, many still experience impaired functional capacity and reduced muscle strength even several months after surgery (Christensen et al. 2020). Physical rehabilitation is considered an essential part of postoperative management and has been shown to improve muscle strength, physical function, pain, and activities of daily living (Saueressig et al. 2021; Konnyu et al. 2023). Nevertheless, the optimal strategy for functional exercise—especially individualized rehabilitation tailored to patient’s needs—remains unclear, and the evidence supporting the benefits of personalized functional training is still insufficient (Saueressig et al. 2021). Previous studies have typically investigated either nursing interventions or physical rehabilitation alone, and few have examined a combined strategy in which risk-based nursing is integrated with individualized functional exercise. Moreover, although the FMEA model has demonstrated effectiveness in proactive management for various diseases, its application specifically in the nursing care of THA patients has rarely been reported, and comprehensive evidence is lacking.

Therefore, the present study aimed to evaluate the effect of an FMEA-based proactive nursing model combined with individualized functional exercise on postoperative hip function in patients after THA. By identifying high-risk steps in the perioperative nursing process through FMEA and combining them with patient-specific functional training, this study intends to fill the existing research gap and provide a practical and

systematic intervention model to optimize postoperative care and improve clinical outcomes.

Materials and methods

Ethics statement

Ethical approval for the study was obtained by the ethics committee of the Affiliated Hospital of Xuzhou Medical University, and informed consent was obtained from all participants. The participants were informed that they could withdraw from the study at any time. This study followed the principle of confidentiality, and all collected data were used solely for research purposes, with assurance that none would be disclosed or lost.

Study participants

This study was a prospective, single-center, randomized controlled trial. By adopting a consecutive sampling method, 100 patients who underwent primary THA in the Affiliated Hospital of Xuzhou Medical University from October 2022 to January 2024 were selected. Inclusion criteria are as follows: (1) underwent THA surgery in our hospital and met the indications for THA (Liu et al. 2025); (2) first-time THA surgery with no surgical contraindications; (3) conscious patients, no cognitive, language, or intellectual impairments, and able to cooperate with the study and a certain level of reading and comprehension (Uysal et al. 2025); (4) stable postoperative vital signs (temperature 36–37.2 °C, respiratory rate 12–20 breaths/min, systolic blood pressure 90–130 mmHg, diastolic blood pressure 70–90 mmHg, heart rate 60–100 beats/min); acid–base balance and electrolyte parameters were generally maintained within normal ranges. Exclusion criteria are as follows: (1) combined with other mental illnesses or severe physical illnesses; (2) abnormal coagulation function; (3) combined with severe cardiovascular and cerebrovascular diseases; (4) accompanied by congenital hip dysplasia or severe osteoporosis.

Sample size calculation

The sample size was calculated using G*Power 3.1.9.7 statistical software, applying the independent-samples *t*-test for mean comparison. To ensure sufficient statistical power to detect differences between groups, an effect size of $d=0.6$ was adopted as the basis for estimation. The significance level α was set at 0.05, and the statistical power ($1-\beta$) was set at 0.80. Under the condition of an allocation ratio $k=1$ (i.e., equal sample sizes in both groups), N_1 and N_2 represented the sample sizes of the two groups, respectively. The calculation yielded a required sample size of 45 participants per group under the same significance level and power. Considering a 10% dropout rate, the final sample size was determined to be

50 participants in each group, resulting in a total of 100 participants. Details are shown in Fig. 1.

Randomization and blinding

Patients who met the inclusion criteria were numbered sequentially according to their admission order. In Excel, “Code” was entered in cell A1, with numbers from 1 to 100 entered consecutively. In cell B1, “Random number” was entered, and 100 random numbers were generated using the formula RAND (), which were then fixed and sorted in ascending order. In cell C1, “Group” was entered; the first 50 smaller random numbers were assigned to the intervention group, and the remaining numbers to the control group. Finally, the codes were rearranged in ascending order. The codes, random numbers, and group allocations were written on cards, which were placed in sealed, opaque envelopes. Patient enrollment and group assignment were carried out by personnel not involved in this study. As this was a comparative study of different nursing interventions, the intervention staff were aware of the nursing and exercise protocols, but blinding was maintained for the study participants, outcome assessors, data collectors, and statisticians.

Treatment methods

The control group received routine nursing and standard postoperative functional exercise. Routine nursing care included the following: (1) preoperative phase: patients received education regarding the disease and surgical procedure and were instructed to fast from food and water in accordance with preoperative guidelines; (2) intraoperative phase: vital signs—including heart rate, blood pressure, respiratory rate, and oxygen saturation—were continuously monitored to promptly detect and manage any unexpected changes; (3) postoperative phase: close monitoring of vital signs was maintained to assess recovery status and ensure proper drainage and catheter patency. Standard health education and psychological counseling were provided to reduce negative emotions and improve disease awareness. Analgesic medication (opioid or non-opioid) was administered according to individual pain levels. Patients were encouraged to mobilize early and follow a stepwise functional exercise program: ankle pump exercises on postoperative day 1; quadriceps isometric contractions and bridge movements on day 2; straight leg raises, hip flexion/extension and hip abduction on day 3 (hip flexion $<60^\circ$); and bedside ambulation with assistance between days 4 and 7. During the first 3 months postoperatively, hip adduction beyond the midline and hip flexion $>90^\circ$ were avoided. Diet was gradually restored according to gastrointestinal function; (4) discharge phase: upon discharge, patients received instructions regarding diet, medication

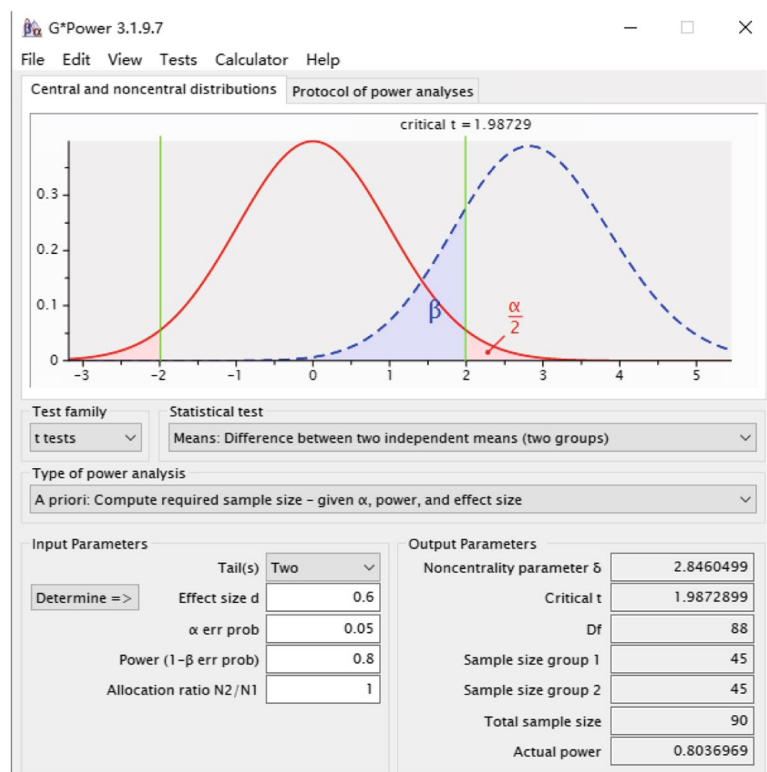


Fig. 1 Sample size calculation using G*Power

use, daily activity, wound monitoring, and follow-up appointments. Telephone reminders were provided to ensure timely outpatient review.

In the intervention group, FMEA-based proactive nursing combined with individualized functional training was implemented in addition to routine care (Yang 2025; Jayamani et al. 2022; Fortier et al. 2021). (1) Team establishment: A dedicated FMEA nursing team was formed, consisting of one attending physician, two ward nurses, and two surgical assistants. Roles and responsibilities were clearly defined, and all members underwent unified training and passed the competency assessment; (2) nursing process development: based on the clinical characteristics of hip arthroplasty patients, a standardized nursing pathway was established, covering preoperative preparation, intraoperative cooperation, postoperative monitoring, complication prevention, and discharge education; (3) failure mode identification: through group discussion, potential failure modes within each step of the nursing pathway were identified, such as insufficient preoperative education, delayed postoperative monitoring, and inadequate implementation of preventive measures for complications; (4) risk assessment: each identified failure mode was evaluated using the risk priority number ($RPN = \text{Severity} \times \text{Occurrence} \times \text{Detectability}$). Higher RPN values indicated higher-risk failure

modes; (5) corrective actions: for failure modes with high RPN values, targeted improvement measures were developed, with clearly assigned responsible personnel and timelines to ensure effective risk mitigation.

Implementation of predictive nursing.

(1) Preoperative phase: Using an outpatient pre-assessment system, an FMEA risk evaluation was performed and an individualized nursing pathway was developed accordingly: ① personalized health education: based on each patient's age, education level and cognitive capacity, preoperative instructions were provided in plain language and supplemented with pictures or videos to help them fully understand the surgical procedure, anesthesia, and postoperative rehabilitation. ② Enhanced preoperative assessment: in addition to routine examinations, special attention was paid to allergy history and psychological status. For patients whose lack of knowledge might affect intraoperative cooperation, trained nurses provided one-to-one education at multiple time points. Psychological counseling was also conducted, and sedatives were administered when necessary for severe anxiety. ③ Operating rooms were kept quiet, clean, and at an appropriate temperature to reduce discomfort and intraoperative stress. (2) Intraoperative phase: the surgical assistants prepared all necessary instruments, equipment, and medications in advance according to the

planned procedure and confirmed their integrity and usability. During surgery, continuous monitoring of vital signs was carried out in line with the risk assessment to detect and manage any unexpected changes promptly. (3) Postoperative phase: vital signs were closely monitored. Antibiotics were administered appropriately according to guidelines. Dressing replacement followed strict aseptic procedures and the original dressing was maintained within the first 48 h. Drainage was monitored every 4 h (color, volume, and characteristics) and the surrounding skin kept clean and dry. Patients were instructed to move carefully to avoid traction of the drainage tube, and drainage bags were changed regularly with attention to signs of infection. ① Pain management: an individualized pain management plan was formulated based on pain assessment, applying multimodal strategies (pharmacological and physical) to ensure adequate postoperative comfort. ② Complication prevention: daily observation of recovery was conducted to identify early signs of infection, bleeding, etc. ③ Nutrition and sleep: a scientific dietary plan was implemented according to gastrointestinal recovery, progressing from clear liquids to soft diet and normal diet, ensuring sufficient intake of vitamins and high-quality protein. Patients were encouraged to maintain adequate sleep and regular routines. Once stable, early ambulation was initiated. (4) Discharge phase: detailed discharge instructions were provided. Through the hospital's mobile health platform, patients received reminders in text, picture, or video format regarding wound monitoring (keeping it clean and dry and seeking medical attention in case of redness, pain, or discharge), regular daily routines, and appropriate activity to promote recovery. Dietary transition principles were reinforced (avoiding greasy and irritating foods). In addition, telephone or WeChat reminders were used to prompt patients to attend follow-up visits on time.

Individualized functional exercise

Within 6 h after surgery, the patient's vital signs and the condition of the affected limb were closely monitored. The affected limb was maintained in an abducted neutral position to avoid external rotation and adduction. The patient's skin was closely observed for any abnormalities such as redness or swelling. Gentle massage of the limb muscles was performed, prophylactic anticoagulants were administered as prescribed, and patients were encouraged to practice deep breathing and effective coughing. The perineal area and urinary catheter were kept clean. From postoperative days 1 to 3, patients were instructed to perform active ankle dorsiflexion and plantar flexion exercises, as well as isometric contraction training of the quadriceps muscles, for 10–15 min per session, 2–3 times per day. From postoperative days 4

to 6, on the basis of the previous exercises, patients were guided to add straight leg raises in the supine position (keeping the leg straight, lifted to about 30°), hip flexion and knee flexion exercises in the supine position (with nurse assistance, hip flexion < 30°), and hip abduction exercises in the supine position. Patients were assisted in gradually transitioning from the supine to the semi-recumbent position, with the head of the bed elevated to less than 90°, and the angle was gradually increased, for 10–20 min per session, 2–3 times per day. From postoperative days 7 to 10, patients were first instructed to perform side-lying hip abduction exercises for 10–20 min per session, 2–3 times per day, followed by transitioning from lying to sitting, allowing the legs to naturally hang over the bedside. Once patients were able to tolerate this position, they were assisted in standing with crutches for 10–30 min per session, 2–3 times per day. After discharge, patients were instructed to continue active functional exercises and, with the assistance of family members, to complete training in activities of daily living, such as dressing, washing, and eating, until they were able to perform these tasks independently. Functional exercise strictly followed the principle of progressing from easy to difficult and from simple to complex, with adjustments made according to the patient's tolerance. Patients were advised to continue rehabilitation exercises after discharge, to use assistive devices correctly, and to avoid premature weight-bearing on the affected limb. It was emphasized that, within 3 months postoperatively, patients should avoid turning toward the affected side and avoid hip flexion greater than 90°. Both groups were continuously nursed for 3 months.

Observation indicators

Clinical indicators

The time to first ambulation after surgery, pain level during activity, and length of hospital stay were compared between the two groups. Pain was assessed using the numeric rating scale (NRS), which ranges from 0 to 10, with 0 representing no pain and 10 representing intolerable pain. Higher scores indicate more severe pain.

Hip joint function

Hip function was evaluated before and after nursing using the Harris hip score (HHS), which was developed by Dr. Harris in the USA and has been shown to have good reliability and validity (Zheng et al. 2014). The scale consists of four dimensions: range of motion (5 points), deformity (5 points), function (46 points), and pain (44 points), with a total score of 100 points. Higher scores indicate better hip joint function.

Psychological status

Anxiety and depression in both groups were assessed before and after nursing using the Self-Rating Anxiety Scale (SAS) and the Self-Rating Depression Scale (SDS), developed by Chinese-American Professor W.K. Zung. Each scale contains 20 items, with the sum of item scores yielding a raw total score (20–80 points). The raw score was multiplied by 1.25, and the integer value was taken as the standard total score (25–100 points). An SAS score >50 indicates anxiety symptoms, and an SDS score >53 indicates depressive symptoms. The scores of both scales are positively correlated with the severity of anxiety and depression.

Quality of life

The quality of life of the patients was evaluated before and after nursing using the SF-36, which includes four domains: physiological function, psychological function, social function, and physical pain, each with a maximum score of 100. Higher scores indicate better quality of life.

Complication rate

The occurrence of postoperative complications was recorded for both groups. Common complications after THA include infection, pressure injuries, deep venous thrombosis of the lower extremities, and joint stiffness.

Nursing satisfaction (Abrahamson 1971)

The Newcastle Nursing Satisfaction Scale (NSNS) was used to assess patient satisfaction with nursing care, aiming to accurately measure the degree of satisfaction with nursing services. Using a questionnaire format, reliable measurements of satisfaction were obtained to help provide individualized and high-quality nursing care. The scale consists of 19 items, each rated on a 5-point Likert scale from 1 (“very dissatisfied”) to 5 (“very satisfied”), with a total score of 95. Scores of 76–95 indicate “excellent,” 57–75 indicate “good,” and 0–56 indicate “poor.” Satisfaction rate (%) = (number of excellent cases + number of good cases)/total number of cases × 100%.

Statistical analysis

Data were analyzed using GraphPad Prism 6.0 software (GraphPad Inc., La Jolla, CA, USA). The normality of continuous variables was assessed using the Kolmogorov–Smirnov test. Normally distributed data were expressed as mean ± standard deviation. Comparisons between two groups were performed using the independent-samples *t*-test, while within-group comparisons were conducted using the paired-samples *t*-test. Categorical data were presented as *n* (%) and analyzed using

the chi-square test or Fisher’s exact test. The significance level was set at $\alpha=0.05$, and a *P*-value < 0.05 was considered statistically significant.

Quality control

- (1) Controlling intervention bias: To minimize potential intervention bias, all members of the intervention team received pre-intervention training. The training covered FMEA-based proactive nursing procedures, individualized functional training protocols, and the standard instructions used for questionnaire administration. Only after successfully completing the training and meeting competency requirements were the team members allowed to carry out the intervention.
- (2) Controlling measurement bias: All questionnaire data were collected by trained professionals using uniform instructions. For participants with low educational levels, staff members were present to explain the questionnaire items and assist with completion. Questionnaires were immediately checked for completeness upon submission, and any missing information was corrected on the spot. To ensure methodological rigor, all clinical and functional assessments were performed strictly according to the predefined protocol. Staff responsible for collecting general demographic and clinical information were independent of the intervention team.
- (3) Data collection and entry: Before data entry, all information was cross-checked against the electronic medical record system to ensure accuracy. Data were then entered using a double-entry method by two independent staff members, followed by consistency checks and preliminary data validation.

Results

Comparison of baseline characteristics between the control and intervention groups

From October 2022 to January 2024, participants were recruited from our hospital. A total of 132 patients were initially enrolled, of whom 21 were excluded for not meeting the inclusion criteria and 11 declined to participate. Ultimately, 100 eligible patients were included and randomly assigned to the control group (*n*=50) and the intervention group (*n*=50). All 100 patients completed the study and all data collection, with no dropouts. In the control group, there were 29 males and 21 females, with a mean age of 68.94 ± 2.55 years and a body mass index (BMI) of 19.04 ± 1.68 kg/m²; surgical indications included femoral neck fracture in 37 patients and femoral

head necrosis in 13 patients. In the intervention group, there were 27 males and 23 females, with a mean age of 69.14 ± 2.60 years and a BMI of 19.16 ± 1.49 kg/m²; surgical indications included femoral neck fracture in 34 patients and femoral head necrosis in 16 patients. There were no statistically significant differences between the two groups in age, sex, BMI, or other baseline characteristics ($P > 0.05$), indicating comparability (Table 1).

Comparison of HHS before and after care between the control and intervention groups

Prior to the nursing intervention, no significant discrepancy was noted in the HHS scores between the two cohorts ($P > 0.05$). Subsequent to nursing care, both cohorts exhibited elevated HHS scores compared to their pre-nursing levels; however, the cohort (function 34.62 ± 2.97 vs 27.94 ± 2.87 ; range of motion 3.64 ± 0.63 vs 2.28 ± 0.45 ; pain 28.98 ± 4.29 vs 23.52 ± 3.83 ; deformity 2.78 ± 0.55 vs 2.02 ± 0.25) under the intervention group displayed significantly higher scores than the

control cohort ($P < 0.05$). This underscores that FMEA model-based proactive nursing alongside individualized functional exercises can more effectively enhance patients' postoperative hip function (Table 2).

Changes in postoperative clinical indicators between the control and intervention groups

Patients in the intervention group got out of bed for the first time significantly earlier than those in the control group (29.12 ± 3.29 h vs 42.20 ± 4.16 h). Their pain scores during activity (4.46 ± 0.86) vs (6.06 ± 1.27) and length of hospital stay (11.40 ± 1.93 days vs 14.84 ± 2.71 days) were also lower than those in the control group ($P < 0.05$). These results reflect that FMEA model-based proactive nursing combined with individualized functional exercise after hip replacement can effectively promote patient recovery and facilitate earlier discharge (Table 3).

Table 1 Comparison of baseline characteristics between the control and intervention groups

Group	Control group (n = 50)	Intervention group (n = 50)	t/ χ^2	P value	Cohen's d/relative risk	95% CI
Sex			0.162	0.687	1.085	0.733 ~ 1.641
Male	29 (58.00%)	27 (54.00%)				
Female	21 (42.00%)	23 (46.00%)				
Age (years)	68.94 ± 2.55	69.14 ± 2.60	0.389	0.698	0.078	-0.314 ~ 0.470
BMI (kg/m ²)	19.04 ± 1.68	19.16 ± 1.49	0.379	0.706	0.076	-0.317 ~ 0.468
Surgical indication			0.437	0.509	1.163	0.763 ~ 1.916
Femoral neck fracture	37 (74.00%)	34 (68.00%)				
Femoral head necrosis	13 (26.00%)	16 (32.00%)				

BMI Body mass index

Table 2 Comparison of Harris hip scores before and after care between the control and intervention groups

Group	Control group (n = 50)	Intervention group (n = 50)	t value	P value	Cohen's d	95% CI
Function (points)						
Before care	21.62 ± 2.19	21.86 ± 2.27	0.538	0.592	0.108	-0.285 ~ 0.500
After care	$27.94 \pm 2.87^*$	$34.62 \pm 2.97^*$	11.430	< 0.001	2.287	1.783 ~ 2.791
Range of motion (points)						
Before care	1.06 ± 0.31	1.02 ± 0.25	0.709	0.48	-0.142	-0.535 ~ 0.250
After care	$2.28 \pm 0.45^*$	$3.64 \pm 0.63^*$	12.370	< 0.001	2.484	1.963 ~ 3.006
Pain (points)						
Before care	18.62 ± 3.66	18.84 ± 3.59	0.303	0.762	0.061	-0.331 ~ 0.453
After care	$23.52 \pm 3.83^*$	$28.98 \pm 4.29^*$	6.716	< 0.001	1.343	0.909 ~ 1.777
Deformity (points)						
Before care	1.06 ± 0.31	1.04 ± 0.20	0.381	0.704	-0.077	-0.469 ~ 0.315
After care	$2.02 \pm 0.25^*$	$2.78 \pm 0.55^*$	8.977	< 0.001	1.779	1.316 ~ 2.242

Compared with pre-care scores in the same group, * $P < 0.05$

Table 3 Comparison of postoperative clinical indicators between the control and intervention groups

Group	Control group (n=50)	Intervention group (n=50)	t value	P value	Cohen's d	95% CI
Time to first ambulation (h)	42.20±4.16	29.12±3.29	17.46	<0.001	−3.488	−4.110~−2.865
Pain score during activity	6.06±1.27	4.46±0.86	7.377	<0.001	−1.475	−1.917~−1.033
Length of hospital stay (d)	14.84±2.71	11.40±1.93	7.322	<0.001	−1.462	−1.904~−1.021

Comparison of anxiety and depression scores before and after nursing in the control and intervention groups

Before the nursing intervention, there was no marked difference in SAS and SDS scores between the two cohorts ($P>0.05$). Following nursing care, both cohorts showed decreased SAS and SDS scores compared to their pre-nursing levels, and the post-nursing scores in the intervention group—SAS (39.02 ± 3.66 vs 46.88 ± 4.52) and SDS (38.98 ± 3.89 vs 49.58 ± 4.05)—were significantly lower than those in the control group ($P<0.05$). This indicates that FMEA model-based proactive nursing combined with individualized functional exercises can effectively mitigate negative emotions in patients after THA (Table 4).

Comparison of quality of life before and after nursing in the control and intervention groups

Before nursing, there were no remarkable differences between the control and intervention groups in any SF-36 dimensions ($P>0.05$). After nursing, SF-36 scores in all dimensions increased in both groups, and the intervention group showed significantly higher scores than the control group in physical function (70.92 ± 6.50 vs 60.06 ± 5.88), mental health (67.88 ± 6.17 vs 58.92 ± 5.71), social function (70.92 ± 6.66 vs 62.84 ± 6.11), and bodily pain (67.82 ± 6.68 vs 59.64 ± 5.24) ($P<0.05$), indicating that FMEA model-based proactive nursing combined with individualized functional exercise can effectively improve postoperative quality of life (Table 5).

Comparison of postoperative complications between the control and intervention groups

The complication rate in the cohort under intervention group (6.00%) was noticeably lower than that in the control cohort (22.00%) ($P<0.05$). This indicates that FMEA model-based proactive nursing combined with individualized functional exercises can effectively reduce the complication rate in patients after THA (Table 6).

Comparison of nursing satisfaction between the control and intervention groups

The nursing satisfaction rate in the cohort under the intervention group (98.00%) was remarkably higher than that in the control cohort (82.00%) ($P<0.05$). This suggests that FMEA model-based proactive nursing combined with individualized functional exercises can improve patients' nursing satisfaction after THA (Table 7).

Discussion

The present study evaluated the effectiveness of proactive nursing based on the FMEA model combined with individualized functional exercise in patients undergoing THA. The results showed significant improvements in multiple clinical indicators, thereby contributing to the current evidence base for post-THA nursing management and providing a novel integrated intervention model.

Patients in the observation group showed earlier postoperative ambulation compared with those in the control

Table 4 Comparison of anxiety and depression scores before and after nursing in the control and intervention groups

Group	Control group (n=50)	Intervention group (n=50)	t value	P value	Cohen's d	95% CI
SAS (score)						
Before nursing	58.40±5.19	57.94±5.01	0.451	0.653	−0.090	−0.482~0.302
After nursing	46.88±4.52*	39.02±3.66*	9.554	<0.001	−1.911	−2.384~−1.438
SDS (score)						
Before nursing	60.24±6.04	61.32±5.99	0.898	0.372	0.180	−0.213~0.572
After nursing	49.58±4.05*	38.98±3.89*	13.350	<0.001	−2.669	−3.209~−2.130

Compared with pre-nursing scores in the same group, * $P<0.05$

SAS Self-Rating Anxiety Scale, SDS Self-Rating Depression Scale

Table 5 Comparison of quality of life before and after nursing in the control and intervention groups

Group	Control group (n = 50)	Intervention group (n = 50)	t value	P value	Cohen's d	95% CI
Physical function (score)						
Before nursing	38.18 ± 4.22	39.02 ± 4.26	0.991	0.324	0.198	−0.195 ~ 0.591
After nursing	60.06 ± 5.88*	70.92 ± 6.50*	8.759	< 0.001	1.752	1.291 ~ 2.213
Mental health (score)						
Before nursing	30.34 ± 2.80	30.14 ± 2.60	0.370	0.712	−0.074	−0.466 ~ 0.318
After nursing	58.92 ± 5.71*	67.88 ± 6.17*	7.534	< 0.001	1.507	1.063 ~ 1.951
Social function (score)						
Before nursing	37.42 ± 4.02	35.94 ± 3.96	1.855	0.067	−0.371	−0.766 ~ −0.024
After nursing	62.84 ± 6.11*	70.92 ± 6.66*	6.323	< 0.001	1.264	0.835 ~ 1.694
Bodily pain (score)						
Before nursing	33.04 ± 2.91	32.82 ± 3.03	0.371	0.712	−0.074	−0.466 ~ 0.318
After nursing	59.64 ± 5.24*	67.82 ± 6.68*	6.808	< 0.001	1.363	0.927 ~ 1.798

* P < 0.05 compared with the same group before nursing

SF-36 Short Form Health Survey

Table 6 Comparison of postoperative complications between the control and intervention groups

Group	Control group (n = 50)	Intervention group (n = 50)	P value	Relative risk	95% CI
Total incidence	11 (22.00%)	3 (6.00%)	0.041*	1.733	1.103 ~ 2.386
Infection	2 (4.00%)	0			
Pressure injury	3 (6.00%)	1 (2.00%)			
Lower limb venous thrombosis	2 (4.00%)	0			
Joint dislocation	3 (6.00%)	0			
Joint stiffness	1 (2.00%)	2 (4.00%)			

* P value was obtained using Fisher's exact test

Table 7 Comparison of nursing satisfaction between the control and intervention groups

Group	Control group (n = 50)	Intervention group (n = 50)	P value	Relative risk	95%CI
Excellent	24 (48.00%)	36 (72.00%)			
Good	17 (34.00%)	13 (26.00%)			
Poor	9 (18.00%)	1 (2.00%)			
Overall satisfaction	41 (82.00%)	49 (98.00%)	0.016*	0.506	0.383 ~ 0.795

* P value was obtained using Fisher's exact test

group, indicating faster recovery of muscle strength, reduced pain, and better postoperative functional capacity. Early mobilization is an important recovery outcome and has been associated with improved clinical prognosis. Our findings are consistent with previous studies showing that FMEA can effectively reduce risks and resource consumption associated with post-event remediation, while supervised functional training benefits patients with insufficient independent function (Fortier

et al. 2021; Lin and Lo 2023). The combination of risk-oriented proactive nursing and individualized functional exercise appears to synergistically promote early mobilization. In addition, the observation group demonstrated lower pain levels during activity and shorter hospital stays. These findings suggest that proactive identification and management of potential risks, combined with targeted exercise, facilitate not only functional recovery but also pain control. This is in line with studies reporting

that specifically prescribed physical rehabilitation can alleviate pain and restore function following orthopedic surgery (Madsen et al. 2025). Shorter hospitalization is clinically important, as it reduces the economic burden and allows faster reintegration into daily life.

Hip function, assessed by HHS, improved more substantially in the observation group than in the control group. This result highlights the importance of developing personalized exercise programs tailored to individual functional levels and recovery needs. Previous studies have similarly found that prescribed exercise-based rehabilitation can enhance joint mobility and reduce the incidence of postoperative complications (Che et al. 2023). From the perspective of behavioral theory, this effect may also be related to improved self-efficacy. According to Bandura's self-efficacy theory, individuals with higher self-efficacy are more likely to engage in and adhere to recommended behaviors. The individualized exercise component, together with proactive communication and guidance from nurses, may have enhanced patients' confidence and willingness to participate in rehabilitation, resulting in improved physical outcomes.

Psychological outcomes were also more favorable in the observation group. SAS and SDS scores significantly decreased after the intervention, indicating improvement in emotional status. Apart from reducing physical discomfort, proactive nursing may enhance patients' perceived control and engagement in their own recovery, thereby mitigating anxiety and depression (Deng et al. 2022). Behavioral reinforcement provided through personalized guidance and timely feedback may further promote positive psychological adjustment.

The incidence of postoperative complications was significantly lower in the observation group. The FMEA model allowed identification of high-risk links in the nursing pathway—such as insufficient drainage monitoring or delayed mobilization—and the implementation of early preventive measures. In combination with individualized functional exercise, it helped reduce the occurrence of infection, deep venous thrombosis, dislocation, and other complications (Madsen et al. 2025). Although the utility of the FMEA model in various clinical contexts has been widely reported, its application in postoperative THA nursing remains limited and the present findings therefore provide a valuable extension of previous work. Nursing satisfaction was markedly higher in the observation group, further emphasizing the importance of individualized and proactive nursing care. By identifying nursing risks in advance, optimizing the care process and addressing individualized functional needs, the intervention enhanced patient-nurse communication and increased overall satisfaction, consistent with prior

studies reporting higher satisfaction levels in patients receiving FMEA-based care (Yang et al. 2022).

Nevertheless, several limitations should be acknowledged. First, this was a single-center study with a relatively small sample size, which may limit the generalizability of the findings. Second, patients were not blinded to the type of care received, and the use of self-reported outcomes may have introduced bias. Third, although the study demonstrated beneficial outcomes of FMEA-based proactive nursing combined with individualized exercise, the specific mechanisms (e.g., increased risk awareness, enhanced self-efficacy, and optimized care workflow) were not fully explored. In addition, practical challenges related to the implementation of the FMEA model in daily nursing practice should be considered, including time constraints, workload, and the need for staff training. To support broader application, healthcare managers and policy makers should consider developing structured training programs and integrating FMEA into standardized nursing pathways. Furthermore, the follow-up period was limited to 3 months; thus, the sustainability of the intervention's effects remains unclear and long-term follow-up is required. Although Bandura's self-efficacy theory was used to interpret part of the results, the current study did not formally assess self-efficacy or other behavioral mediators; therefore, the potential behavioral mechanisms underlying the intervention effects remain unclear and should be addressed in future research.

Conclusion

In conclusion, proactive nursing guided by the FMEA model combined with individualized functional exercise significantly improves early recovery, hip function, psychological status, and patient satisfaction while reducing postoperative complications in THA patients. These findings suggest that this integrated approach may offer a valuable strategy for optimizing post-operative management and enhancing patient outcomes. This integrated FMEA-based proactive nursing model with individualized functional exercise may serve as a practical and scalable strategy for improving postoperative care quality in THA patients and could be incorporated into standard clinical nursing pathways to support early recovery and risk prevention. However, given the limitations of this single-center quantitative study, the results should be interpreted cautiously. Future multicenter studies with larger sample sizes and mixed-methods designs are needed to confirm the long-term effects and to explore the mechanisms underlying the success of FMEA-based nursing strategies.

Authors' contributions

J.L. and Y.Q.C. finished the study design, K.Z. and X.Z. finished the experimental studies, Y.H.Z. finished the data analysis, J.C. finished the manuscript editing. All authors read and approved the final version of the manuscript.

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Data availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

Declarations

Ethical approval and consent to participate

Ethical approval for the study was obtained by the ethics committee of the Affiliated Hospital of Xuzhou Medical University, and informed consent was obtained from all participants.

Consent for publication

The participant has consented to the submission of the manuscript to the journal.

Competing interests

The authors declare no competing interests.

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