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Original Article

Effects of preoperative Otago exercise program on rehabilitation in total knee arthroplasty patients

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Abstract: Unspecialized perioperative functional exercise guidance for lack of professional rehabilitation therapists in China delayed the rehabilitation of total knee arthroplasty (TKA) patients. To investigate the intervention effect of preoperative Otago exercise program (OEP) on rehabilitation in TKA patients, 200 TKA cases from October 2018 to October 2019 were selected and divided into control group and OEP group by random. The control group was administrated with routine perioperative orthopedic nursing while the OEP group was administrated with Otago exercise program besides the regular orthopedic nursing. On the postoperative third, seventh and fourteenth days, range of motion (ROM) of the knee joint in OEP group increased significantly compared with the control group. HSS knee score, Barthel index score, and modified falls efficacy scale (MFES) score of OEP group were significantly higher than those of the control group. Therefore, preoperative OEP is beneficial to TKA patients in accelerating rehabilitation and lowering the risk of falling.

Keywords: Otago exercise program, total knee arthroplasty, muscle strength, ROM

Introduction

Total knee arthroplasty (TKA) refers to the application of artificial prosthesis instead of the intrinsic knee joint to improve the knee joint function. It has been used as an effective surgery to treat late-stage osteoarthritis, rheumatoid arthritis, traumatic arthritis etc. TKA also alleviates severe symptoms including pain and restricted movement, joint deformity and other joint dysfunction [1]. The application of artificial joint prosthesis helps the patients to rebuild normal knee function, reduce pain and achieve better quality of life. Therefore, TKA has been widely used all over the world because of its good therapeutic effects [2]. As for the perioperative management of TKA patients, despite a variety of rehabilitation modalities available, the optimal rehabilitation protocol has yet to be determined. In China, many TKA patients cannot get systematic and professional functional perioperative exercise guidance for lack of professional rehabilitation therapists, thus the rehabilitation of the affected knees is delayed or interrupted, which affects the quality of life after TKA on a large scale [3].

Enhanced recovery after surgery (ERAS) used a multimodal approach before and after surgery in order to improve the care and subsequent clinical outcomes. The principal components of enhanced recovery programs include measures to achieve preoperative optimization of patients, patient education, perioperative anesthetic techniques, perioperative surgical techniques, and postoperative rehabilitation [4]. Several studies applied a preoperative training program with the aim of speeding up recovery after TKA. However, few have reported clear benefits, especially in regards to the function of knee joints [5, 6]. Previous studies have shown that aerobic training and resistance training enhance the tolerance to surgery and the muscle strength of the affected limb [7]. Nevertheless, more studies are needed to identify the effectiveness of preoperative training program on postoperative rehabilitation of TKA patients.

The Otago exercise program (OEP) is a home-based balance and strength training program that reduces falls and promotes muscle strength in daily life. The program includes aerobic training and resistance training, which helps to improve balance and muscle strength [8]. The most significant effects on fall reduction induced by the Otago program are seen in patients who are 80 years or older [9, 10]. Considering

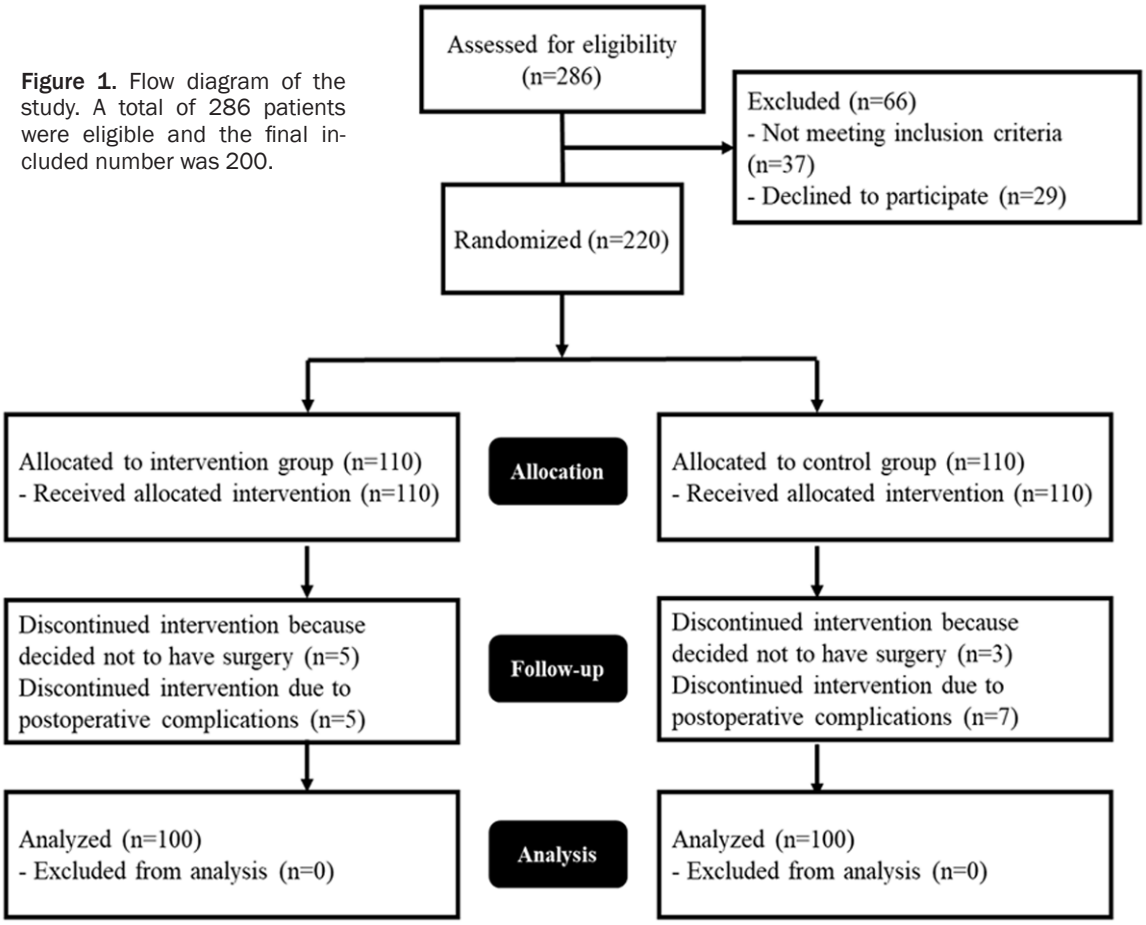

Figure 1. Flow diagram of the study. A total of 286 patients were eligible and the final included number was 200.

that muscle strength and balance are critical factors of TKA postoperative rehabilitation, it is plausible that preoperative OEP may provide further benefits. The aim of this study is to explore the effects of preoperative OEP on TKA patients in regards to reducing postoperative limb swelling, fall occurrence, enhancing knee function and MFES score. It is hypothesized that the program would be effective with these individuals in accelerating rehabilitation and lowering risks of falling. We constructed an intervention plan based on the follow-up intervention measures of Otago exercise, and explored more effective intervention strategies of functional exercise before total knee arthroplasty.

Materials and methods

General information

A total of 286 patients who underwent total knee arthroplasty in our hospital from October 2018 to October 2019 who met the inclusion criteria were incorporated as participants and 200 patients were analyzed (**Figure 1**). The study was approved by the Xijing Hospital Ethics Board. All subjects were divided into control group (100 cases) and OEP group (100 cases) by randomization. Inclusion criteria included: (1) TKA surgical candidates confirmed by CT or MRI examination and scheduled for TKA; (2) no venous thrombosis was found by ultrasound before surgery; (3) patients who volunteered to participate in the project and signed the informed consent before the operation. Exclusion criteria: (1) patients with severe complications unsuitable for surgery; (2) patients with movement disorders in other joints which may affect rehabilitation; (3) patients decided to quit after the study began. The general demographic data of the two groups showed no significant differences in age, education level, personal income, occupation, prosthesis fixation mode, etc. ($P > 0.05$). The results are shown in **Table 1**.

Randomization and blinding

All subjects were randomly assigned to each group in individual and hierarchical approach-

Table 1. General information comparison of the two groups n (%)

	Control Group (n=100)	Intervention Group (n=100)	X^2/z	*P* value
Gender			0.040	0.841
male	56 (56.00)	54 (54.00)		
female	44 (44.00)	46 (46.00)		
Degree			0.644	0.520
Primary School or Below	20 (20.00)	16 (16.00)		
Junior high school	28 (28.00)	30 (30.00)		
Senior high school	40 (40.00)	40 (40.00)		
College degree or above	12 (12.00)	14 (14.00)		
Profession			0.211	0.976
Retirees	34 (34.00)	36 (36.00)		
In-service stuff	30 (30.00)	28 (28.00)		
Unemployed	8 (8.00)	10 (10.00)		
Other	28 (28.00)	26 (26.00)		
Monthly income			0.351	0.725
< 3000	20 (20.00)	18 (18.00)		
3000-5000	36 (36.00)	36 (36.00)		
5001-8000	40 (40.00)	40 (40.00)		
> 8000	4 (4.00)	6 (6.00)		
Prosthesis Fixation			0.051	0.822
Cemented	74 (74.0)	72 (72.00)		
Uncemented	26 (26.00)	28 (28.00)		

es. Each subject receives a random sequence from the researcher, which is enclosed in a sealed envelope in case of unintended interference. Furthermore, the design of the study formed barrier to blinding both the subjects and the intervention nurses. Therefore, the data analysis worker and outcome evaluator were kept blinded to the groups which the subjects were allocated to.

Study design

Patients in control group received regular orthopedic nursing measures, including health education, perioperative functional exercise, regular follow-up by telephone, etc. [11]. The OEP group completed an Otago exercise training program prior to surgery, 3 days per week for a total of 4 weeks in addition to the regular perioperative nursing measures. The detailed intervention procedures were as follows:

(1) First contact: Researchers met patients and introduced the plan details including procedures, probable effects and duration. Physical function of each patient was comprehensively assessed to determine the amount and intensity of exercise.

(2) Determination of plan: After education and communication with patients, the rehabilitation goals were determined and a feasible individualized exercise program was established. In addition, patients were also given an OEP direction, a personalized exercise calendar, and requirements for muscle strength.

(3) Functional exercise: Once the program of functional exercise was determined, the patient conducted targeted functional exercise on the affected limb under assistance to enhance the muscle strength of the affected limb.

① Warm-up exercises included movement of the head, neck, trunk, ankle and body extension. Each extension was repeated for a total of 5 times.

② Muscle strength exercises refer to the knee pressing exercise: The patients lay down with a soft pillow under the ankle joint and the anterior thigh muscles tighten. Patient was asked to extend the knee as much as possible to touch the bed for 5 to 10 seconds, and then relax for 5 to 10 seconds. Repeat this process for 30 times. Straight leg raise exercise: The patient lay on the bed with both legs straight. Patient was asked to alternately raise both legs from the bed, stay at the highest position for 10 s, and then gently drop off. Repeat for a total of 10 times. Intensity of the exercise was gradually increased. Knee extension: The patient was seated still with a sandbag tied over the ankle. Patient was asked to lift the sandbagged leg off the ground keeping the leg straight, and then drop off. Knee flexion: The patient stood straight with the sandbag tied over the ankle of one leg. Then the patient was asked to flex the knee of the sandbagged leg as much as possible and then return to the original position.

③ Balance training included knee flexing, inverted walking with tools, 8-shaped routes walking, sideway walking, standing on tiptoe, walking on tiptoe, one leg standing and so on. The difficulty of the training is classified into four grades from low to high, with an A referring to the lowest difficulty level and D the highest difficulty level. Patients were trained for about 30 to 40 min each time, 3 times a week.

Procedure

Anesthesia method was chosen by the anesthetist. Arthroplasty was conducted using cemented or cementless prosthesis (based on the surgeon's judgement). The same postoperative rehabilitation protocol directions were used for every participant. The training was performed for almost 30 min a day starting on the first day post-operation. All patients were discharged on the fifth day post-operation and followed the protocol given by the doctors. Every patient was followed up at regular intervals.

Outcome evaluation

Range of motion (ROM): Large goniometry was used to measure active ROM before the operation and on the first, third, seventh and fourteenth day after surgery. To measure ROM, the patient took a supine position. Flexion of the knee was measured with hip on the same side at 90° flexion. Use the goniometer to measure the ROM of the knee. The center of the tool was placed at the side view of the knee joint, and arms of the goniometer were aligned in longitudinal axis of the femur and the tibia. As the knee was extended or flexed, the movable arms provided a measure of the movement degree. The knee was moved to maximum flexion and the range was measured in degrees [12]. ROM was measured before operation and on the postoperative first, third, seventh and fourteenth day.

Barthel index for activities of daily living (ADL): This scale was the most widely used daily life ability rating scale in orthopaedic clinical practice. This scale contained 10 items, which were used to evaluate patients' feeding, bathing, grooming, dressing, bowel control, bladder control, toilet use, transfers (bed to chair and back), mobility on level surfaces and stairs climbing. The scale had good reliability and validity with the Cronbach's coefficient more than 0.92. The total score of the scale was 100. Higher score indicated better independence of the patient [13]. The index was evaluated before operation and on the postoperative 14th day.

Hospital for special surgery (HSS) knee score: The scoring standard was a scoring system proposed by the hospital for special surgery in New York. There were 7 items including pain, function, range of motion, strength, flexion deformity and joint stability. Deduction items include the need for a walking aid, varus or valgus deformity and incomplete extension. The evaluation results were classified into four grades, excellent (≥ 85), good (70-84), moderate (60-69) and poor (≤ 59) [14]. The index was evaluated before operation and on the postoperative 14th day.

The Western Ontario and McMaster Universities osteoarthritis index (WOMAC) knee score: WOMAC was a popular patient-reported outcome measure (PROM) to evaluate the status of hip and knee osteoarthritis. The questionnaire consisted of 24 items in 3 subscales: pain (5 items); stiffness (2 items); physical function (17 items). WOMAC was extensively used in researches and studies [15]. The index was evaluated before operation and on the postoperative 14th day.

Modified falls efficacy scale (MFES): The scale consisted of a one-page form including 14 questions each related to a particular activity (such as dressing, taking a bath etc.). The first 9 items focused on patients' indoor activities, and the last 5 items evaluated patients' outdoor activities. Compared with the original scale, the MFES aimed to determine how confidently the patients feel they can undertake each activity on a scale of 0 to 10 (from not confident at all to completely confident) [16]. The MFES had a Cronbach's alpha coefficient of 0.977 with a content validity coefficient of 0.637-0.926 [17].

Data analysis

The data were analyzed and processed using SPSS 22.0. For quantitative variables, the comparisons between different groups were analyzed using the Student t-test. For qualitative variables, the chi-square test was used. Comparisons of quantitative variables at different time points were analyzed with ANOVA for repeated measurement. If the result was posi-

Table 2. Comparison of ROM before and after TKA in two groups (x ± sd)

Group	Before TKA	3 d after TKA	7 d after TKA	14 d after TKA
Control group (n=100)	55.82±6.41	86.50±8.24	92.40±7.36	102.70±6.74
OEP group (n=100)	56.22±7.12	87.10±5.51	96.25±6.01	110.22±8.83

Table 3. Comparison of HSS, WOMAC and Barthel score before and after TKA

Group	WOMAC		HSS		Barthel score	
	Pre-operation	Post-operation	Pre-operation	Post-operation	Pre-operation	Post-operation
Control group (n=100)	67.51±7.23	23.6±3.96	42.63±4.12	66.24±7.96	35.66±9.86	63.50±4.55
OEP group (n=100)	69.02±9.42	24.5±4.42	43.55±5.07	73.52±9.42	34.02±8.33	68.66±4.18
t	1.272	1.517	1.408	5.903	1.271	8.351
P value	0.205004	0.1310	0.160626	< 0.001	0.205376	< 0.001

tive, then a q test was used. For all cases, $P < 0.05$ was taken as the difference was statistically significant.

Results

Comparison of general information in two groups

Of all the participated patients, 55% were male (56% in the control group and 56% in the intervention group); 18% had an educational level of primary school or below; 35% were retired; 19% had an income of lower than 3000 RMB, a total of 73 patients used cemented prosthesis and 27 used cementless prosthesis (**Table 1**). As shown in **Table 1**, there was no significant difference between two groups.

Comparison of ROM before and after TKA

ROM of the control group was compared with that of the intervention group before TKA and on the third, seventh and 14th day postoperation. In both groups the mean maximal ROM was increased after TKA ($P < 0.05$). There was no significant difference in the mean maximal ROM between the groups before the operation and 3 days after the operation. On the seventh and fourteenth day after surgery, a significant difference was seen between two groups ($P < 0.05$). On postoperative 14th day, there was a remarkable increase in ROM of the OEP group compared with the control group, as shown in **Table 2**.

Comparison of HSS, WOMAC and Barthel score before and after TKA

The clinical results indicated that preoperative and postoperative WOMAC scores showed no significant difference between two groups. As for HSS and Barthel score, postoperative scores of control and OEP group had significant difference ($P < 0.001$). The OEP group had remarkable improved score compared with control group, suggesting that OEP provided improved clinical outcomes compared with the control group as measured by HSS and Barthel scores (**Table 3**).

Comparison of MFES score before and after TKA

Before surgery, the MFES score of both groups showed no significant difference ($t=1.501$, $P > 0.05$). No statistically significant difference was found in MFES scores one month after surgery compared with the score before surgery in control group ($t=1.646$, $P > 0.05$). In the OEP group, MFES score significantly increased ($t=6.979$, $P < 0.05$) after the surgery. One month after surgery, OEP group had a MFES score of 81.37±9.94, higher than 76.55±7.81 in the control group ($t=3.813$, $P < 0.05$) (**Figure 2**), as shown in **Tables 4** and **5**.

Discussion

With variation in utilization rates across different regions and countries, the numbers of TKA cases continue to grow worldwide [18]. However, outcome of the surgery is not well defined and can be affected by many factors [19]. Although most patients have a good clinical outcome after knee replacement, multiple studies reported that 20% or more of patients are not satisfied with the outcome. On the other hand, as concluded by the 2003 National Institutes of Health consensus statement, the use of rehabilitation services is perhaps the

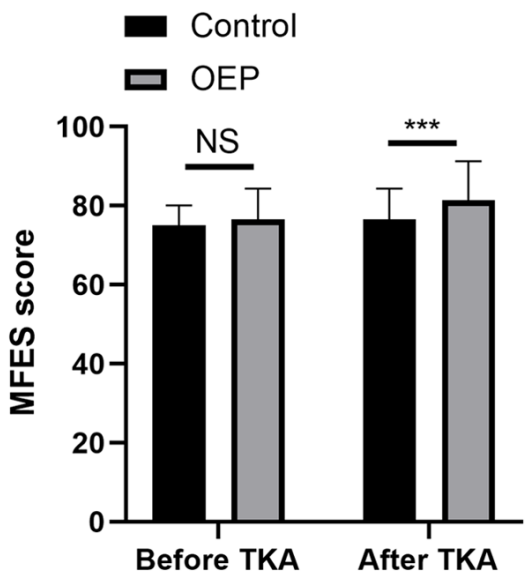

Figure 2. Comparison of MFES score. Before the operation, no significant difference was observed in MFES score between control and OEP groups. After operation, the OEP group had a higher MFES score compared with control group. ***P < 0.001 compared with control group. OEP, Otago exercise program; MFES, Modified falls efficacy scale.

most understudied aspect of the perioperative management of TKA patients and there is no evidence supporting the generalized use of any specific perioperative rehabilitation intervention [20]. Therefore, more work needs to be done to increase the proportion of patients who have remarkable pain relief and function improvement after TKA [21, 22]. Among all the development and work to achieve the goal, perioperative recovery programs including ERAS and perioperative nursing are essential [4].

Evidences accumulate that the ERAS program improves outcomes of TKA [4, 23]. Nevertheless, preoperative nursing is seldom discussed. Preoperative nursing care is defined as nursing care starting when the surgical intervention is considered necessary and ending when patient is transferred to undergo surgery. Preoperative nursing care is cost-effective when surgical process and management are optimized for patients. Nurse-led preoperative assessments are safe and effective in preoperative assessment, especially in orthopaedic surgery [24]. Nurses provide careful patient screening and assessments which enhances communication between patients and medical staff. Careful preoperative nursing care helps patients to better tolerate surgery and furthermore, helps patients recover faster from surgery with better clinical outcomes. In this study, we mainly studied the effects of preoperative Otago exercise program on total knee arthroplasty patients.

The original OEP was a 1-year home-based falls prevention exercise program that resulted in an average 35% reduction in falls in trials conducted in community-dwelling people aged 75 and older in New Zealand. As reported, the OEP was also the most cost-effective program for those aged over 80 [25]. The OEP is carried out by physiotherapists and nurses. It is designed to be carried out over 12 months (or more recently). The nurse makes approximately five visits within a certain period and makes monthly phone calls to the participant to encourage adherence. The OEP is a novel model of physical therapy set conducted in a longer period. The program sets combine patient engagement and medical services [26]. Studies show that the Otago exercise program, including aerobic training and resistance training, helps improve balance and muscle strength and prevent falls in daily life [27]. Considering that muscle strength and balance are critical factors of postoperative rehabilitation, it is plausible that preoperative OEP may provide further benefits for TKA patients.

Data suggests that ROM of both groups significantly declined on the third and seventh day after surgery compared with before. ROM of patients who received OEP exhibits a larger ROM compared with those who didn't. OEP helps participants in knee muscle training. The muscles adjacent to the knee are strengthened, and therefore the range of motion of knee is effectively increased. The strengthened muscle enables the knee to flex and extend more easily. Therefore, application of OEP facilitates TKA patients' movement.

Through the work of research members, personalized OEP was formulated so as to enhance the muscle strength of the affected limb. Evaluation of knee function using different scales is a direct way to understand the knee damage degree and to observe the effects of treatment. HSS and WOMAC score are two most commonly used knee function scores with good reliability, validity and sensitivity [28]. HSS is mainly used in the observation of

Table 4. MFES item mean scores

MFES item	Before TKA		After TKA	
	Control group	OEP group	Control group	OEP group
1	7.03	6.73	6.99	6.99
2	5.56	5.61	6.84	6.22
3	6.14	6.51	6.92	7.26
4	7.26	6.89	6.25	7.55
5	6.16	6.71	4.46	7.17
6	7.36	6.61	5.93	7.02
7	6.39	6.49	5.54	6.87
8	5.74	5.93	5.39	7.24
9	4.23	5.25	4.52	3.59
10	4.31	4.63	4.65	4.08
11	3.09	2.54	3.97	2.96
12	4.31	3.59	4.68	5.11
13	3.41	2.65	4.78	4.1
14	4.02	3.97	5.63	5.21
Total	75.01±5.15	74.11±3.07	76.55±7.81	81.37±9.94

Table 5. Comparison of MFES score

Group	Before TKA	After TKA	t	P
Control group (n=100)	75.01±5.15	76.55±7.81	1. 646	0.1013
OEP group (n=100)	74.11±3.07	81.37±9.94	6.979	< 0.001
t	1.501	3.813		
P value	0.1349	0.0002		

TKA recovery and WOMAC score is used in the assessment of osteoarthritis. Our study shows that after OEP intervention, WOMAC score in both teams had no significant difference while HSS score significantly increased. This may be caused by the large proportion of relatively younger patients in this study since WOMAC score is less sensitive in younger patients and elder patients tend to have obvious improvements by WOMAC evaluation. WOMAC score is a patient-reported outcome measure method; this may be another reason why changes in WOMAC are not significant. The Barthel index score has good correlation with mortality, requirement for institutional care and length of hospital stay. It helps to assess systematic disability and monitor the rehabilitation progress as an independent indicator of the depedency level. Our results demonstrate the effects of OEP on patients' activities of daily living independence. Conducting OEP on patients strengthened surrounding muscles. Stronger muscles facilitate daily activities. Thus the independence of activities of daily living is achieved.

After OEP intervention, the MFES score of patients was higher than that before and the control group. These data suggest that the OEP-based exercise training program can effectively improve the self-confidence of patients against falls, which were similar to those of elderly community patients receiving OEP in China as previously reported [29]. The preoperative functional training of OEP enhances the muscle strength adjacent to the knee and prevents the muscle atrophy. Patients gradually get used to active training and passive training, thereby improving the knee function and enhancing the confidence of avoiding falling, which is consistent with the previous studies [16].

Our initial focus of the study was on patients' knee function as well as subjective feelings, however, all the included evaluations have deficiency in one aspect and no single score can reflect the whole status of the patient. For this reason, our study finally came to include not only the actual knee status but also patient's experiences and feelings about the effects of OEP. Therefore, there is the possibility that the results may be affected by patients' mind status and the reliance on researchers. Still, the improvement in ROM indicates the objective effects of OEP on TKA patients and the knee function scores reflect improvement in subjective feeling of TKA patients, identifying the positive impacts of preoperative OEP on TKA rehabilitation.

Conclusion

Results of our study indicated that TKA patients performed OEP had increased ROM (1-3 degree) after surgery. There was no difference in postoperative increased WOMAC score in both groups. Significant increases in postoperative HSS (7.28) and Barthel score (5.16) were detected in OEP group. Thus Otago exercise training has significant clinical significance in improving ROM, knee function and daily life function. In preventing falls, OEP increased

MFES score for 4.82. The improvements in ROM, knee function and daily life function increased over time and long-term results remain to be seen. In summary, Otago exercise training improves ROM, knee function and daily life function of TKA patients after surgery, and is worthy of promotion in TKA rehabilitation.

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Disclosure of conflict of interest

None.

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