Original Article

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The Effect of a Single Session of Preoperative Exercise Training on The Rate of Functional Improvement in Patients Who Underwent Total Knee Arthroplasty at a Tertiary Hospital in Southern Thailand: A Retrospective Cohort Study

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Abstract:

Objective: To evaluate the effect of a preoperative exercise training program before total knee arthroplasty (TKA) and the factors associated with functional outcomes after TKA.

Material and Methods: A retrospective cohort study was conducted. Patients were selected to receive a preoperative exercise training program before TKA. The changes in the Knee Society Score (KSS) were evaluated before and after surgery at 6, 12, and 24 weeks between the preoperative exercise and the standard care groups.

Results: The mean objective scores (KS-OS) and functional scores (KS-FS) were significantly improved at 6 (T1), 12 (T2), and 24 (T3) weeks following surgery. The effect of a single session of preoperative exercise training had no significant difference in both scores (KS-OS T1 p-value=0.53, KS-OS T2 p-value=0.59, KS-OS T3 p-value=0.63; KS-FS T1 p-value=0.16, KS-FS T2 p-value=0.94, KS-FS T3 p-value=0.99). There was no significant difference in the knee range of motion at 6 (p-value=0.68), 12 (p-value=0.12), and 24 (p-value=0.05) weeks after surgery. Ages of 65 years and older and length of stay in hospital, equal to or greater than 5 days, were associated with lower functional outcomes.

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Conclusion: The preoperative exercise training program did not affect functional outcomes. Advanced age and longer length of stay in the hospital were associated with poor functional outcomes.

Keywords: functional performance, knee arthroplasty, knee osteoarthritis, physical therapy, prehabilitation

Introduction

Osteoarthritis (OA) of the knee is a degenerative joint disease that is typically the result of wear and tear and progressive loss of articular cartilage[1]. There is a 16%-17% incidence among adults aged 50 to 75 years old[2]. Moreover, 7.5% of adults over the age of 55 experience knee pain and disability[3]. Total knee arthroplasty (TKA) is an effective treatment for decreasing pain and increasing physical activity for patients with severe OA[4]. The outcome after TKA depends on many factors. One of them is physical therapy after surgery[5]. Petterson et al. found that the progressive strength training enhanced quadriceps strength significantly (p-value=0.007); with, the timed-up-and-go test (TUG) being 24.0% faster (p-value=0.004), and a 15.0% longer distance on the 6-min walk (6MW) significantly (p-value=0.003)[6]. In addition, previous studies have shown that preoperative functional status was related to functional ability following TKA[7,8] Preoperative exercise strengthens the muscles around the knee joint, and improves walking ability. Consequently, the length of stay in the hospital can be reduced[9,10]; therefore, preoperative exercise may be an important factor for better results after knee surgery[11].

Patients with knee OA have difficultly accessing physical therapy in the hospital because most of them are elderly and have knee pain. Thus, it is necessary to develop a single session of preoperative exercise training to provide the opportunity to access the prehabilitation programs[12]. However, evidence supporting preoperative rehabilitation in patients undergoing TKA still has been inconclusive[13]. Some studies showed preoperative exercise did not affect postoperative outcomes, whereas other studies found significant improvements. The reasons for inconsistent results may be due to different prehabilitation protocols in each study having small sample sizes (ranging from 21 to 165)[13].

Therefore, the aim of this study was to evaluate the effect of preoperative exercise training before TKA and to evaluate the factors associated with functional outcomes after TKA.

Material and Methods

Study design and subjects

A retrospective cohort study was conducted. A total of 459 patients were included in the study. The inclusion criteria were patients with primary knee OA having undergone TKA; from January 2016 to December 2020. Thirty-one patients with secondary knee OA caused by congenital abnormalities, posttraumatic, metabolic disorders or inflammatory joint diseases were excluded. Moreover, osteoarthritis patients received other operations; such as unicompartmental knee replacement were excluded. Eventually, 428 patients were included in the study (Figure 1).

Operation and rehabilitation details

All patients underwent a cemented TKA and received a standard postoperative rehabilitation protocol[14]. Before the day of surgery, patients were selected to receive a preoperative rehabilitation program, depending on the surgeon's opinion. The preoperative rehabilitation protocol used in the hospital was a single session of preoperative exercise training by a physiotherapist approximately 2 weeks before surgery (Table 1). They were advised to perform all exercises for 2-3 sets per day until the day of surgery. These exercises aimed to increase the range of motion and strength of the muscles in the lower limbs before TKA. Patients who did not receive the preoperative exercise training were advised only of the operation details.

A postoperative rehabilitation program was initiated in all patients 2-4 hours postoperatively with the standard protocol for TKA (Table 1). The functional goal before discharge was self-ambulation with a walker and pain-free active knee flexion to 90 degrees[15]. Before discharge, it was emphasized to patients that they should perform the exercise every day. The follow-up date was set at 6, 12, and 24 weeks after surgery.

Table 1 Preoperative and Postoperative exercise protocol

Exercise program
Deep breathing exercise: 10 repetitions per set
Ambulation training with a walker on flat surfaces and on stairs
Knee exercise/active assisted (seat) 10 repetitions per set each: weight free
- Knee flexion
- Knee extension
Knee exercise/active assisted (supine) 10 repetitions per set each: weight free
- Isometric quadriceps muscle
- Heel slide
Lower extremity exercise 10 repetitions per set each: weight free
- Leg slides abduction/adduction
- Straight leg raises
- Buttocks squeezes and bridging
- Ankle pump and stretching of the calf muscles
Upper extremity exercise 10 repetitions per set each: dumbbell 0.5 kg
- Shoulder press
- Bicep curls

Assessments

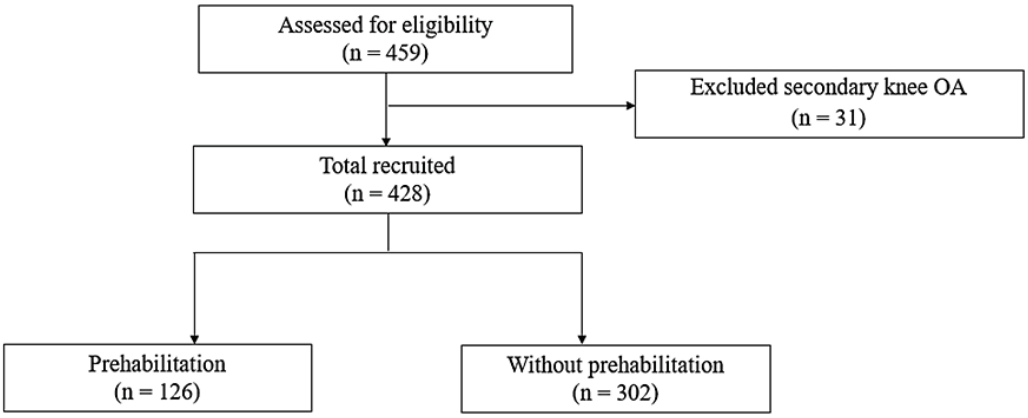
Baseline evaluations included age, gender, body mass index (BMI), smoking status, comorbidities (diabetes mellitus, hypertension, dyslipidemia, chronic kidney disease, previous stroke, previous myocardial infarction and spinal stenosis), severity of knee OA and operative time. The severity of OA was assessed from knee radiographs using the Kellgren Lawrence (KL) system by rehabilitation doctors (P.C. and C.L.)[16]. The severity was classified into 4 levels: from doubtful to a severe degree.

The outcome was a change in the Knee Society Score (KSS) after surgery. This score reflected functional abilities, which were evaluated before and after surgery at 6, 12, and 24 weeks by the surgeons (V.Y., T.H. and K.I.)[17]. The scores were classified into objective scores (KS-OS) and functional scores (KS-FS). KS-OS measured knee pain, range of motion (ROM), anteroposterior stability, mediolateral stability, flexion contracture, extension lag and alignment. KS-FS was determined by walking ability, walking up and down stairs and using gait aids. Both types of KSS ranged from 0-100. A higher score suggests better knee clinical outcomes. The clinically significant change occurs in patients whose KS-OS and KS-FS improved by at least 9 and 10 points, respectively. Furthermore, significant clinical benefits occur in patients whose scores improved by at least 40 and 39 points, respectively[18]. All data were reviewed and retrieved from the electronic medical records via the Hospital Information System. This study was approved by the Human Research Ethics Committee.

Statistical analysis

Mean±standard deviation (S.D.) and median ±interquartile range (IQR) were used to describe normally and non-normally distributed continuous variables, respectively. Percentages were used to describe categorical variables. Student's t-test for normally distributed data and Wilcoxon rank-sum test for non-normally distributed data were used to compare continuous variables between the groups. The chi-squared test was used to compare categorical variables between the two groups and Fisher's exact test was used in case of having a small sample size.

The mixed effect random intercept linear regression, including a three-way interaction term between preoperative exercise, sequence of the knee (the unilateral or bilateral TKA) and time of follow-up was analyzed to compare KS-OS, KS-FS and ROM between groups over time.



OA=osteoarthritis

Figure 1 STROBE flow diagram

Table 2 Patient and clinical characteristics

Characteristics of participants	Preoperative exercise group, (%) (N=126)	Standard care group, (%) (N=302)	p-value
Age (years)			0.822
<65	34 (27.0)	86 (28.5)	
65–74	64 (50.8)	141 (46.7)	
75–84	27 (21.4)	69 (22.8)	
≥85	1 (0.8)	6 (2.0)	
Gender			0.572
Male	10 (7.9)	31 (10.3)	
Female	116 (92.1)	271 (89.7)	
Body mass index (kg/m^2)			0.813
Underweight (<18.5)	1 (0.8)	5 (1.7)	
Normal (18.5-22.9)	13 (10.3)	31 (10.3)	
Overweight (23-24.9)	14 (11.1)	42 (13.9)	
Obese (≥25)	98 (77.8)	224 (74.2)	
Smoking status			0.324
Never smoked	123 (97.6)	296 (98.0)	
Current smoker	2 (1.6)	2 (0.7)	
Former smoker	0 (0.0)	3 (1.0)	
Smoker, current status unknown	0 (0.0)	1 (0.3)	
Unknown	1 (0.8)	0 (0.0)	
Comorbidities			
Diabetes Mellitus	25 (19.8)	65 (21.5)	0.796
Hypertension	69 (54.8)	195 (64.6)	0.073
Dyslipidemia	57 (45.2)	142 (47.0)	0.818
Chronic kidney disease	1 (0.8)	1 (0.3)	0.503
Previous stroke	5 (4.0)	8 (2.6)	0.538
Previous myocardial infraction	0 (0.0)	9 (3.0)	0.064
Spinal stenosis	8 (6.3)	13 (4.3)	0.518
Kellgren Lawrence classification			0.444
3	13 (10.3)	41 (13.6)	
4	113 (89.7)	261 (86.4)	
Operative time (minutes)*	135 (120, 150)	135 (120, 155)	0.263

*The values are presented as the median (interquartile range)

Potential confounders of KS-OS, KS-FS and ROM were identified in the Directed acyclic graph. (Supplement 1) Random elements were: surgeons, preoperative exercise and sequence of the knee. The time of follow-up was the fixed components. This study included the sequence of knee, as primary OA commonly occurs in both knees. Therefore, the functional outcome of the patients' post-unilateral TKA should be lower than one with bilateral TKA[19]. In addition, this also included surgeons in the model to reduce selection bias.

A linear mixed model was used to evaluate the associated factors for functional outcomes after TKA[20]. Age was stratified into subgroups as: adult, young elderly, middle elderly and old elderly to provide more clinical information. Also, the BMI was stratified into underweight, overweight, obese and morbid obesity. The statistical significance level was set at p-value<0.05. The analysis was done using Stata version 14.2[21,22].

Results

Patient and clinical characteristics

The preoperative exercise group and the standard care group were similar in age, gender, BMI, smoking status, comorbidities, KL classification and operative time (Table 2).

Postoperative outcomes

In both the preoperative exercise group and the standard care group, the mean KS-OS and KS-FS were significantly improved at 6, 12, and 24 weeks following surgery compared with the baseline. When focusing on the range of motion of the knee, no significant improvement between groups at 6, 12, and 24 weeks after surgery was found (Table 3).

Considering the effect of the preoperative exercise training, there was no significant difference in either KS-OS, KS-FS or ROM between the preoperative exercise and the standard care group. (Table 3, Figure 2, and Figure 3)

For the associated factors, age of 65 years or older, and length of stay in hospital at least five days, were associated with poor functional outcomes after TKA (Table 4).

Discussion

This study's results did not reveal any significant effect of the preoperative exercise training program on either objective or functional scores. This contrasts with the meta-analysis by Gränicher, which reported that a prehabilitation program could significantly enhance knee function in the short term (≤4 weeks) and mid-term

Table 3 The Knee Society Score by time

Variables	Time point	Preoperative exercise (N=126)	Standard care (N=302)	p-value*
KS-OS	Pre-operation	54.1±3.9	54.0±6.4	-
	Post-operation 6 weeks	96.1±4.0	96.4±3.5	0.53
	Post-operation 12 weeks	98.5±2.8	98.1±4.0	0.59
	Post-operation 24 weeks	99.1±1.8	98.8±3.5	0.63
KS-FS	Pre-operation	38.7±15.8	30.1±18.1	-
	Post-operation 6 weeks	48.0±18.2	54.3±16.2	0.16
	Post-operation 12 weeks	58.0±15.5	61.5±16.4	0.94
	Post-operation 24 weeks	62.2±14.1	66.0±13.8	0.99
ROM	Pre-operation	121.1±1.9	122.7±1.8	-
	Post-operation 6 weeks	119.2±1.8	120.2±1.7	0.68
	Post-operation 12 weeks	123.4±1.8	122.8±1.7	0.12
	Post-operation 24 weeks	125.1±1.9	123.7±1.7	0.05

KS-OS=objective scores, KS-FS=functional scores, ROM=range of motion of the knee
The values are presented as mean±standard deviation (S.D.)
*Using mixed effect random intercept linear regression on the change of value by time (time reference: prior surgery)

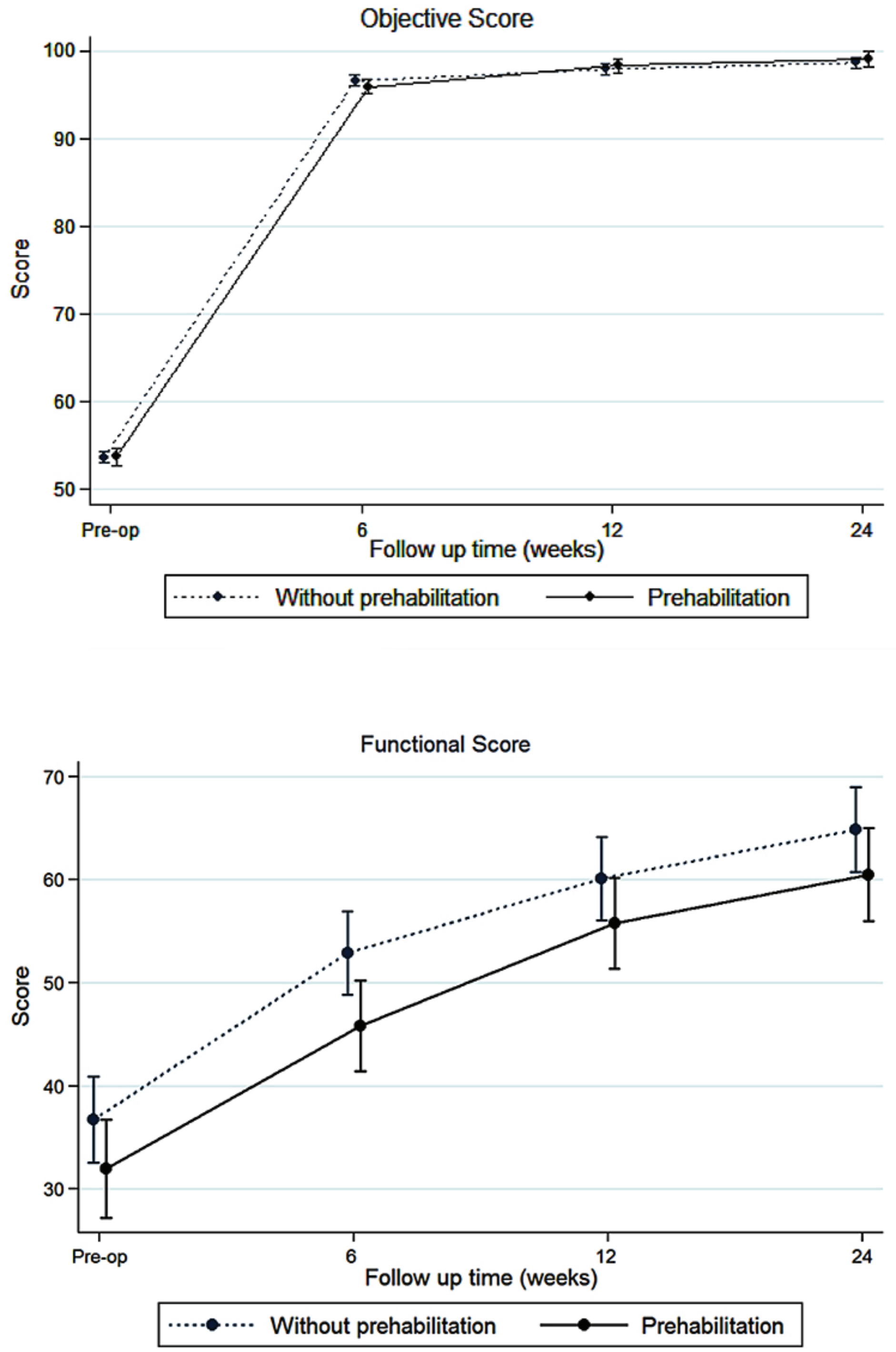


Figure 2 Preoperative and postoperative knee objective scores and knee functional scores

Table 4 The associated factors affecting the knee functional scores (compare at 6 weeks)

Factors	Adjusted factors	Coefficient	95% CI	p-value
Age (years) (reference: age <65)	None			
≥65		-4.20	(-8.26, -0.14)	0.04
≥75		-11.26	(-15.81, -6.71)	***<0.001***
Sex (reference: male)	None			
Female		-3.88	(-9.23, 1.47)	0.16
BMI (kg/m^2) (reference: normal)	None			
Underweight (<18.5)		-5.86	(-20.15, 8.43)	0.42
Overweight (<23)		0.30	(-6.89, 7.49)	0.96
Obese (≥25)		-0.90	(-7.00, 5.21)	0.77
Morbid obesity (≥30)		-0.23	(-6.66, 6.19)	0.94
Comorbidities	None			
Diabetes mellitus		-0.92	(-5.30, 3.46)	0.68
Hypertension		-1.61	(-5.28, 2.06)	0.40
Dyslipidemia		-1.75	(-5.29, 1.78)	0.33
Chronic kidney disease		-4.35	(-32.96, 24.25)	0.77
Previous stroke		-9.94	(-20.27, 0.38)	0.06
Previous myocardial infraction		1.85	(-9.88, 8.26)	0.74
Spinal stenosis		-0.83	(-17.11, 39.82)	0.86
KL classification (reference: 3)	Operative time, BMI	1.52	(-2.97, 6.02)	0.51
Operation time (minutes)	KL classification, BMI	-0.06	-0.13, 0.01	0.10
Length of stay (reference ≤3 days)				
4	Body mass index	-0.58	(-4.23, 3.06)	0.75
≥5	Comorbidities	-7.33	(-12.21, -2.44)	***0.003***

BMI=body mass index, KL=Kellgren Lawrence, kg/m^2=kilogram per meters squared
[a]The negative values of effect estimated refer to lower knee functional score compared to the reference

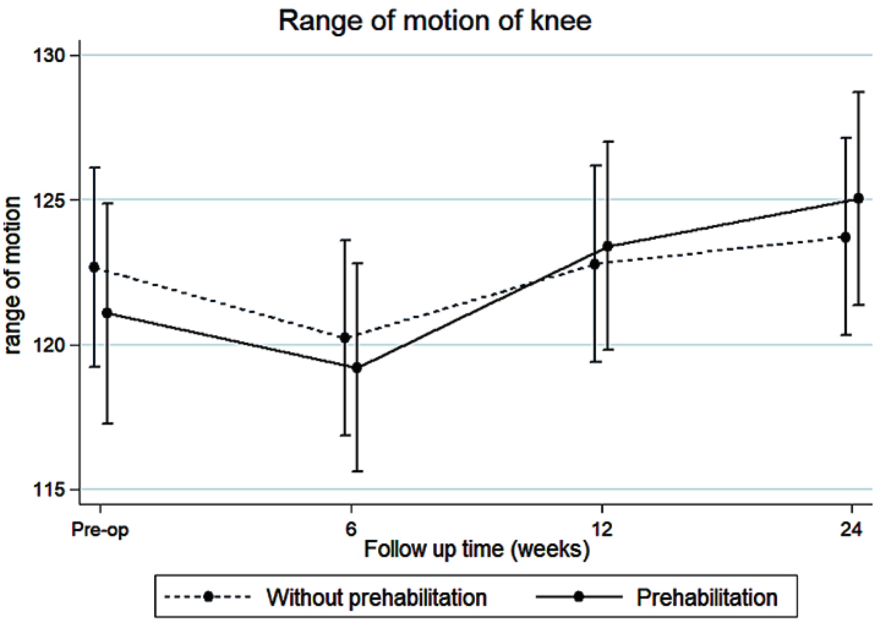


Figure 3 Preoperative and postoperative knee range of motion

(3 months) post-surgery. However, this meta-analysis exhibited considerable heterogeneity due to the variety of prehabilitation protocols. Moreover, many studies included in Gränicher's et al had exercise programs markedly different from this study's[23]. In line with these findings, Matassi et al., who followed a similar exercise protocol, also observed no difference in KSS after surgery between the participants in the preoperative exercise group and those in the control group[11]. Furthermore, numerous studies employing a hospital-based single-session protocol failed to show any positive effects of prehabilitation on pain scores, WOMAC scores, or quality of life after surgery[24,25]. This can be explained by preoperative exercise performed in a single-session could not reach an ideal intensity and duration for which should be required to change fitness capacity[14]. The American College of Sports Medicine guidelines recommends strengthening exercise at least 2 days per week, with 8-12 repetitions in each exercise[26]. In addition, several studies showed that prehabilitation could improve outcomes after TKA when the protocol was set regularly as 3-4 times a week[27,28]. The hospital-based single-session preoperative exercise has benefits as it is practical and feasible for all patients; however, it also requires continued exercise at home[29]. Therefore, adherence to home-based exercise is important. Unfortunately, there was no information on exercise adherence in our population. From Beinart et al, home-based exercise adherence was only 30.0-50.0%[30]. Thus, it was assumed that participants in our study might not have performed regular exercise which was adequate to improve fitness in these patients. For this reason, monitoring of exercise adherence should be added to improve the efficacy of the protocol. Regarding the Weingkum study, they discovered the combination of home-based preoperative exercise and weekly monitoring phone calls could considerably improve knee functions[27].

Although the preoperative exercise group showed more improvement in knee ROM than the standard care group, there was no statistically significant difference. Nevertheless, patients could better learn to exercise before surgery, because they do not feel any discomfort and postoperative pain. However, there are still various factors that affect good postoperative knee ROM beyond the prehabilitation program, including preoperative ROM status, surgical techniques, implant design, postoperative complications, and compliance with postoperative exercise[31].

To our knowledge, regular exercise (three times a week) at least six to eight weeks before surgery seems to be appropriate to improve physical functions, pain and muscle strength after surgery[14]. The exercises should include both resistive and flexibility exercises[14]. A home-based setting is more suitable than a hospital-based exercise, a sit provides better feasibility[29]. However, techniques for encouraging home-based exercise adherence and feedback are needed to reach the recommended protocols. Nowadays, many options are available for remote exercise monitoring, for example, telephone, teleconference, applications and logbooks[32]. Considering the associated factors, it was found that age and length of stay in the hospital affect knee functional outcomes after TKA. For older patients, functional ability and muscle strength normally decline with age[33]. Moreover, older patients have a higher prevalence of comorbidities[34]. Thus, physiologic change and comorbidities are related to poor physical activities. Additionally, the longer length of stay in the hospital could be related to adverse events, such as surgical site infection and deep vein thrombosis during hospitalization, which might affect a patient's functional outcome[35].

The limitation of this study is its retrospective study design; however, it had a large sample sizes being adequate for 80% power to test the mean difference between groups. Furthermore, the participants were selected by the surgeon's opinion leading to the risk of selection bias. A directed acyclic graph was used as the basis for modeling and adjusted confounding factors, such as unilateral/bilateral TKA and surgeons in the model to reduce the risk of bias. Additionally, this study could be subject to an information bias, since the data was collected by the surgeons that performed a TKA. Neithertheless, the Knee Society Score is recognized for its strong validity and reliability, being quantified as an objective measure[17].

For future work, home-based prehabilitation with telemonitoring should be studied, since it is more feasible fore COVID-19 pandemic situations. Moreover, a comparison between different exercise protocols should be conducted to determine the best prehabilitation program. Further studied should be focused on the effect of pain control on preoperative exercise programs, as pain affects preoperative exercise.

Supplementary figure 1: Directed acyclic graph for potential confounders of Knee Society Score (KSS).

Conclusion

A preoperative exercise training did not affect functional outcomes after TKA. Moreover, advanced age and longer length of stay in the hospital were associated with poor functional outcomes after TKA.

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Conflict of interest

There are no potential conflicts of interest to declare.

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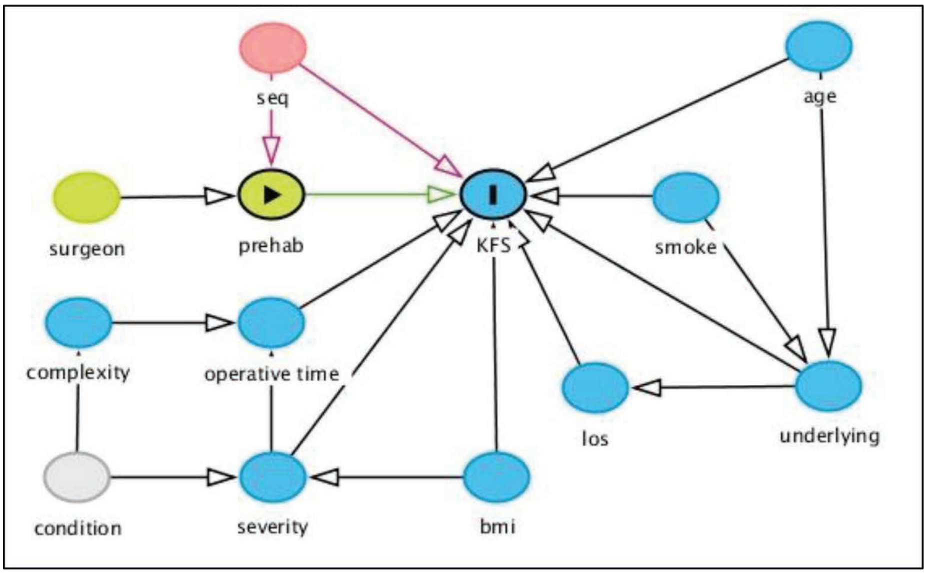

KFS=knee functional score, seq=sequence of knee, prehab=preoperative exercise, bmi=body mass index, los=length of stay, underlying=underlying disease

Supplementary figure 1 Directed acyclic graph