Assessing Functional Outcomes and Pain Intensity Variations After Total Knee Arthroplasty: A Comparative Analysis of Pain Block Techniques

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ABSTRACT

Objective: This study aimed to compare post–total knee arthroplasty (TKA) outcomes (function, pain, and quadriceps strength) between femoral nerve block (FNB), intra-articular block, and a control group. In addition, it sought to identify predictors of postoperative functional capacity.

Methods: Fifty-four TKA patients were evaluated. Preoperative assessments included quadriceps strength and the Oxford knee score. Postoperative assessments on days 1 and 3/4 included the timed up and go (TUG), Elderly Mobility Scale, and Five Times Sit-to-Stand tests. Pain levels, hospitalization duration, surgical time, complications, and falls were also recorded.

Results: No significant differences in functional outcomes, pain levels, or quadriceps strength were found between the FNB, intra-articular block, and control groups, except for the TUG test on day 3/4, which favored FNB ($P < 0.01$). Preoperative quadriceps strength was a valuable predictor of early functional outcomes, with FNB improving TUG scores on day 3/4.

Discussion: The choice of pain block technique had limited effect on short-term functional outcomes post-TKA, except for early mobility as measured by the TUG test on day 3/4. Preoperative quadriceps strength markedly predicted initial functional performance. Additional research is needed to enhance postoperative pain management and early rehabilitation strategies.

Clinical Trial Registration Number: NCT05478005.

The prevalence of total knee arthroplasty (TKA) is increasing globally, projected to rise by 85% in the United States by 2030.[1] Effective postoperative rehabilitation is essential to prevent complications, yet it often faces challenges due to pain management.[2–4]

Post-TKA pain management methods encompass peripheral nerve blocks, analgesics, and patient-controlled analgesia.[5] Opiates, while effective, carry

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the risk of tolerance and dependence.[6] Peripheral nerve blocks, especially femoral nerve blocks (FNB), are known for their pain relief benefits and reduced opiate consumption.[2,7–9] However, FNB poses a risk of nerve injury, potentially affecting quadriceps muscle strength and patient mobility.[8] An alternative to FNB is the intra-articular block (IAB), which involves injecting analgesics directly into the knee joint during surgery, posing a minimal risk of nerve injury.[10,11]

Despite extensive research on TKA pain management, an optimal protocol for balancing pain relief and patient mobility remains elusive. Previous research frequently overlooks a functional aspect, giving more emphasis to outcomes related to pain and the usage of opioids.[12] Some studies suggest that although there may be no notable differences in hospitalization duration and pain levels between FNB and IAB, the latter is associated with reduced opiate consumption. Garg et al[13] found that FNB resulted in reduced quadriceps muscle strength throughout the initial 12 hours postsurgery, accompanied by slightly diminished pain levels at specific time points. Functional evaluations, particularly the timed up and go (TUG) test, demonstrate the superior functional performance of individuals who received IAB in the early days after the surgery.[12,14] Nevertheless, a necessity exists for more extensive evaluations of patient functionality.[12] Our study sought to fill this void by comparing the effect of FNB and IAB on mobility, pain management, and quadriceps strength after TKA, thereby offering valuable insights to aid in informed surgical decisions and rehabilitation planning.

Patients and Methods

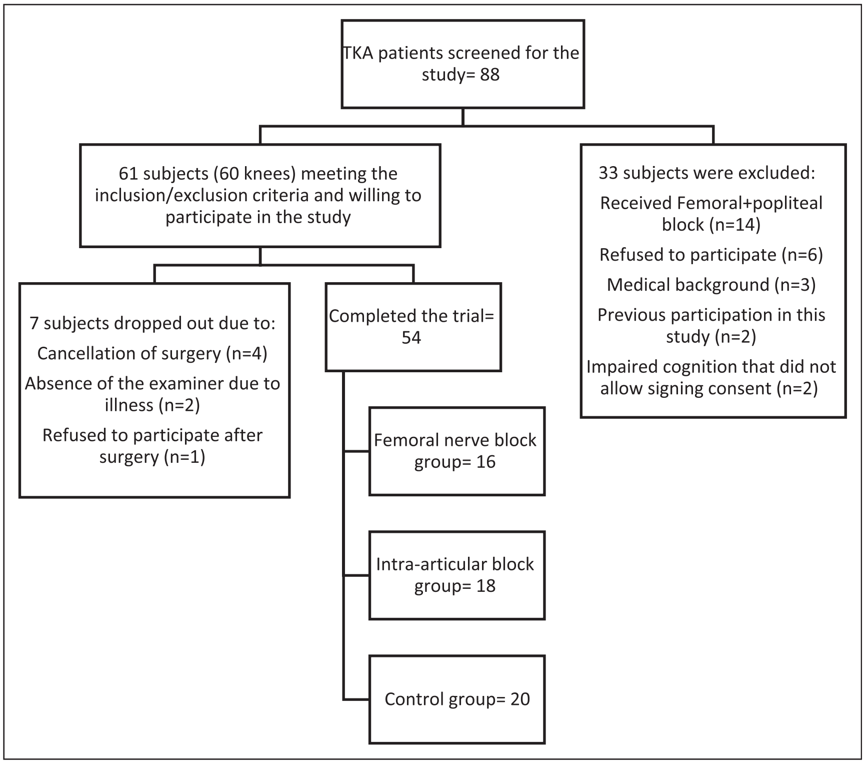
This study was a controlled clinical trial involving men and women aged 18 years and older, with no specified age limit, undergoing scheduled elective knee replacement surgery and scoring 1 to 3 on the American Society of Anesthesiologists index. Exclusion criteria included individuals undergoing revision knee replacement, those experiencing chronic pain or opiate use exceeding 3 months, individuals with previous lower limb neurologic deficits, cognitive impairments affecting their ability to provide consent, or those unable to cooperate postsurgery or transfer after a cardiac or neurologic event. Initially, 88 subjects were identified, and 54 successfully completed the study, forming three groups: control (n = 20), FNB (n = 16), and IAB (n = 18). Figure 1 illustrates the participant selection process. Baseline characteristics, including age, sex, body mass index, preoperative Oxford Knee Score, and quadriceps muscle strength (Table 1), showed no significant differences among the groups.

Ethical approval for the study was obtained from the Helsinki Committee of the Medical Center. Participants were asked to complete the OKS questionnaire in their preferred language.[15–18] In addition, the strength of the quadriceps muscle, which was intended for surgery, was assessed using a manual dynamometer.[19] All assessments were conducted by a single physiotherapist who remained blinded to the surgical method throughout the study.

Patients underwent knee replacement surgery with or without a block, as determined by the surgeon or anesthetist at the time of the operation. Patients were not informed of the chosen method. Both the orthopedics department director and the knee unit head, who performed the surgeries, were senior surgeons with extensive expertise and specialized training in TKA. The IAB method was used by the department manager during the operation. The knee unit manager was unaware of the blocking method, as the anesthesiologist was responsible for selecting the appropriate pain-blocking technique during the operation. In the case of the FNB, an anesthesiologist administered 15 mL of 0.5% ropivacaine into the patient's femoral nerve using a single ultrasound-guided injection. The IAB method involved the injection of a composition of 40 mL of 1% lidocaine, 20 mL of 0.5% bupivacaine, 1 mL of epinephrine, and 100 mg of hydrocortisone into various knee structures. All patients received general anesthesia.

On the first postoperative day (POD 1), functional tests were conducted, including the TUG test,[20] the Elderly Mobility Scale (EMS),[21] the five times sit to stand,[22] and quadriceps muscle strength assessments with a manual dynamometer.[23] These evaluations occurred on POD 1 and POD 3/4. During the hospitalization period, nursing staff assessed the patient's pain intensity three times a day using the Numeric Pain Rating Scale (NPRS).[24] Furthermore, the physiotherapist in charge also assessed pain levels at rest and after walking using the NPRS. After their hospital stay, the principal investigator collected extra information from patient records. These data encompassed details such as age, sex, BMI, total length of hospitalization, duration of the surgical procedure, painkiller consumption during the hospital stay, occurrence of complications, and any instances of falls. All patients received daily physical therapy from the POD 1 until their discharge. Descriptive statistics analysis was conducted to examine the outcome measures. For continuous variables across

Figure 1



Flowchart of the sampling process

the three groups, a one-way analysis of variance was used. In instances where assumptions were violated, sample sizes were limited, or data intervals were narrow, the nonparametric Kruskal-Wallis test was used as an alternative. Furthermore, a comparative analysis was executed between the groups to ensure uniform examination times for patients assessed on the third POD and those examined on the fourth POD. To account for patients unable to participate in physical therapy or assessments on the initial POD due to factors such as pain or physical limitations, a thorough examination was performed among the three groups to ensure equitable distribution of cooperative patients on the first POD. Predictors of early TKA function were assessed through multiple regression analysis. The analytical procedures were conducted using SAS 9.4 software, with a predetermined significance level of $P \leq 0.05$.

Results

Table 2 presents the summarized results of functional and mobility assessments. Although no significant

Table 1. Demographic and Perioperative Patient Data

Variable	Femoral Nerve Block (n = 16)	Intra-articular Block (n = 18)	Control Group (n = 20)	P
	M ± SD	M ± SD	M ± SD	
Age (yrs)	70.00 ± 5.66	72.17 ± 6.98	68.15 ± 7.73	0.19
Sex (men/Women)	4/12	2/16	7/13	0.25
BMI	33.29 ± 6.65	34.99 ± 4.40	32.52 ± 4.08	0.16
Preoperative OKS	44.13 ± 8.20	43.72 ± 8.57	46.10 ± 8.29	0.60
Preoperative quadriceps muscle strength (N·m)	18.22 ± 6.14	17.67 ± 7.13	18.01 ± 8.78	1.00

BMI = body mass index; M = median; OKS = Oxford Knee Score

Table 2. One-Way Analysis of Variance of the Differences Between the Three Groups in the Results of the Functional and Mobility Tests After Surgery

Variable	Femoral Nerve Block (n = 16)	Intra-articular Block (n = 18)	Control Group (n = 20)	
	M ± SD	M ± SD	M ± SD	*P*
TUG POD 1[a]	63.85 ± 94.23	51.82 ± 108.43	91.32 ± 127.69	0.46
TUG POD 3/4[a]	19.57 ± 47.93	30.26 ± 85.25	60.81 ± 94.84	0.008
EMS POD 1[a]	10.80 ± 4.00	10.90 ± 3.40	11.00 ± 4.50	0.99
EMS POD 3/4[a]	15.70 ± 2.80	13.60 ± 3.40	13.30 ± 4.10	0.14
5TSTS POD 1[b]	29.90 ± 15.90	34.90 ± 18.30	67.10 ± 92.00	0.45
5TSTS POD 3/4[b]	26.00 ± 11.80	27.40 ± 14.10	46.30 ± 48.50	0.76

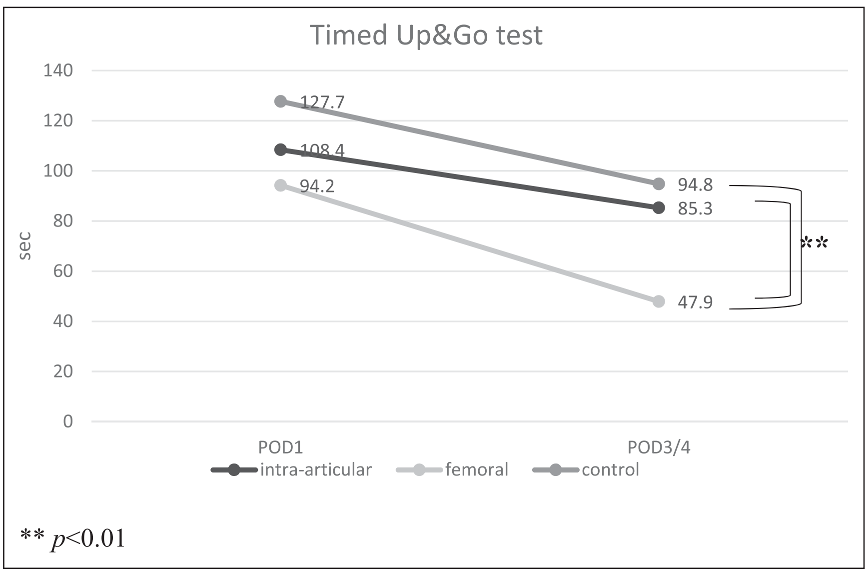
5TSTS = 5 times sit to stand; EMS = elderly mobility index; M = median; POD = post-operative day; SD = standard deviation; TUG = timed up & go
[a]One way ANOVA.
[b]Kruskal Wallis.
*$P \le 0.05$, **$P \le 0.01$.

differences were observed in the TUG test results among the three groups on postoperative day 1, a statistically significant disparity was detected on days 3/4 (P = 0.008). Remarkably, the FNB group displayed enhanced TUG test performance, characterized by shorter completion times compared with both the IAB and control groups. Figure 2 illustrates these TUG test outcomes. In addition, the results of the EMS and five times sit to stand assessments on POD 1 and POD 3/4 did not reveal any notable differences.

Table 3 provides an overview of the pain assessment results (NPRS) at rest and after walking in the three groups. No statistically significant differences were identified in pain levels before and after walking on both POD 1 and POD 3/4. Furthermore, there were no notable fluctuations in pain levels during rest from the day of surgery through postoperative day 4. In addition, no substantial differences were observed among the groups in quadriceps muscle strength on POD 1 and POD 3/4. Detailed results of the muscle strength assessments at all time points are available in Table 4 and Figure 3.

No significant differences were observed in opiate and nonopiate pain reliever consumption among the groups

Figure 2



Graph showing the timed up and go test results for the three groups, 1 day after surgery and 3 to 4 days after surgery. **$P < 0.01$.

Table 3. Differences Between the Three Groups in the Results of the Numeric Pain Rating Scale After Surgery

Variable	Femoral Nerve Block (n = 16) M ± SD	Intra-articular Block (n = 18) M ± SD	Control Group (n = 20) M ± SD	*P*
NPRS-rest POD 1[a]	6.63 ± 2.55	6.44 ± 2.45	6.60 ± 2.91	0.98
NPRS-rest POD 3/4[a]	5.07 ± 2.76	5.06 ± 2.59	6.11 ± 2.49	0.39
NPRS-active POD 1[a]	7.27 ± 1.53	6.60 ± 2.64	7.63 ± 2.19	0.42
NPRS-active POD 3/4[a]	5.40 ± 3.09	4.88 ± 2.63	6.74 ± 2.08	0.10
NPRS POD 0[b]	1.10 ± 1.10	1.90 ± 1.10	1.40 ± 1.20	0.17
NPRS POD 1[b]	2.40 ± 1.60	2.10 ± 1.20	2.30 ± 1.00	0.76
NPRS POD 2[b]	2.00 ± 1.10	1.60 ± 1.30	2.40 ± 1.40	0.36
NPRS POD 3[b]	1.90 ± 1.60	1.90 ± 1.10	1.60 ± 0.80	0.57
NPRS POD 4[b]	1.50 ± 1.60	1.10 ± 0.60	1.30 ± 0.80	0.81

Active = level of pain after walking; M = median; NPRS = numeric pain rating scale; POD = post operative day; rest = level of pain at rest; SD = standard deviation
[a]One way ANOVA.
[b]Kruskal–Wallis.
*$P \leq 0.05$, **$P \leq 0.01$.

(Table 5). However, the IAB group had significantly longer surgical times compared with the FNB and control groups, and patients in the IAB group had extended hospital stays (Table 6). No significant differences were observed in postoperative falls, complications, or patient cooperation on day 1 after surgery among the groups.

The results of multiple regression analyses are presented in Table 7. In the analysis, quadriceps muscle strength emerged as a significant predictor of TUG performance on the first postoperative day ($\beta = -0.52$, $P < 0.01$), accounting for 25% of the variance ($R^2 = 0.25$). Regarding TUG performance on day 3/4 after surgery, both femoral block ($\beta = 0.46$, $P < 0.01$) and quadriceps muscle strength ($\beta = -0.31$, $P < 0.05$) were found to be influential predictors, explaining 31% of the variance ($R^2 = 0.31$).

In addition, quadriceps muscle strength was found to be a significant predictor of EMS on day 1 after surgery ($\beta = 0.48$, $P < 0.01$), explaining 24% of the variance in EMS outcomes ($R^2 = 0.24$). This relationship persisted for EMS on day 3/4 after surgery ($\beta = 0.40$, $P < 0.01$), accounting for 28% of the variance ($R^2 = 0.28$). Consequently, higher preoperative quadriceps strength was associated with better d EMS results on both POD 1 and POD 3/4.

Discussion

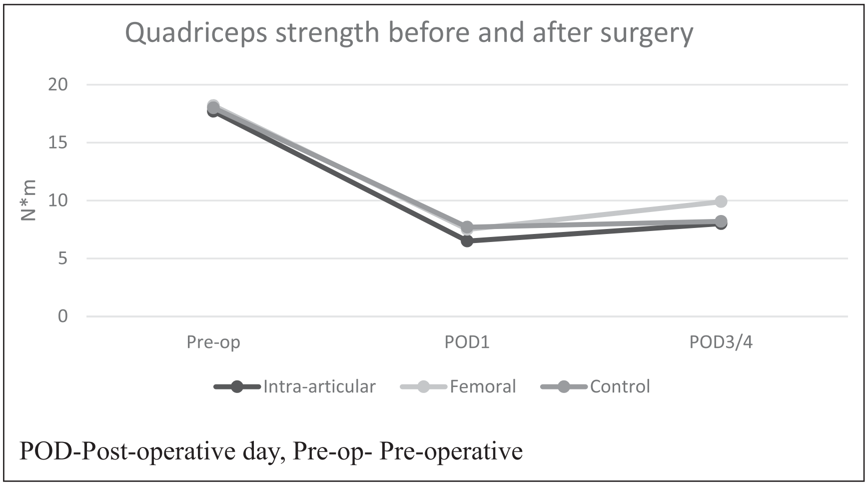
In this clinical trial, we compared two post–knee replacement surgery blocking techniques (FNB and IAB) with a control group that received no block treatment. We thoroughly assessed patient function, pain levels, and muscle strength. This study is the first to provide valuable insights into the effectiveness of FNB and IAB by comparing their outcomes with those of the control group.

Table 4. One-Way Analysis of Variance of the Differences Between the Three Groups in Quadriceps Muscle Strength After Surgery

Variable	Femoral Nerve Block (n = 16) M ± SD	Intra-articular Block (n = 18) M ± SD	Control Group (n = 20) M ± SD	*P*
Quadriceps strength POD 1 (N·m)	7.48 ± 2.30	6.51 ± 1.80	7.70 ± 2.80	0.32
Quadriceps strength POD 3/4 (N·m)	9.85 ± 2.80	7.98 ± 2.30	8.20 ± 2.30	0.09

M = median; POD = postoperative day; SD = standard deviation.

Figure 3



Graph showing the results of the quadriceps muscle torque test at the three time points. POD = postoperative day; preop = preoperative

Our main objective was to assess postoperative functionality. Patients who received FNB showed markedly better performance in the TUG test on day 3/4 after surgery compared with both the control and IAB groups. No notable difference was found between the control and IAB groups. Notably, no previous studies have directly compared these groups' functionality. We anticipated that patients in the IAB group would experience better functional outcomes. This assumption was primarily based on a 2017 study comparing FNB and IAB.[14] However, our results contradicted this expectation, possibly due to differences in techniques, such as the use of a double local injection in the 2017 study.

The pain levels' results revealed no notable differences in pain levels among the three groups (FNB, IAB, and control group) throughout the early postoperative phase, spanning from the day of surgery to the 4th day afterward. These findings align with the outcomes of two systematic reviews from 2016 to 2022[25,26] that compared FNB and IAB, indicating no discernible distinctions in pain levels during both movement and rest in the early postoperative period. Our study also supported recent findings from the 2022 study of Lychagin et al, which was not included in previous reviews. Lychagin et al[26] investigated pain levels and quadriceps muscle recovery in patients who received IAB and a combined femoral-sciatic block, comparing them with a control group that did not receive any blocks. They found notable benefits from the combined block only 6 hours after surgery, with no discernible differences afterward. These results partially align with our study, where we observed no pain level variations among the three groups on POD zero.

Our investigation closely monitored patients' use of both opiate and nonopiate pain relievers during their hospital stay. Notably, we observed that all three groups had similar patterns of pain reliever usage, suggesting that nerve blocks did not influence medication consumption. These findings are consistent with a 2016 review,[25] which found no notable differences in intravenous opiate usage between the FNB and IAB groups during the initial 3-day postsurgery. Although a 2016

Table 5. **Opiate and Nonopiate Pain Reliever Consumption**

Variable	Femoral Nerve Block (n = 16) M ± SD	Intra-articular Block (n = 18) M ± SD	Control Group (n = 20) M ± SD	*P*
Opiate pain reliever consumption (mL/d)	22.21 ± 13.42	18.88 ± 10.16	19.73 ± 13.45	0.87
Nonopiate pain reliever consumption (mL/d)	2028.94 ± 1329.83	1938.29 ± 861.74	1908.97 ± 813.60	0.94

M = median; SD = standard deviation. Kruskal–Wallis Test.

Table 6. **Group Differences in Operation Duration, Hospital Stay, Complications, Falls, and Treatment Compliance on the First Postoperative Day (Kruskal-Wallis Test)**

Variable	Femoral Nerve Block (n = 16) M ± SD	Intra-articular Block (n = 18) M ± SD	Control Group (n = 20) M ± SD	*P*
Duration of surgery (min)	87.00 ± 20.80	112.50 ± 15.20	76.60 ± 9.30	<0.001
Length of hospitalization (d)	4.88 ± 1.50	6.39 ± 1.50	4.70 ± 1.60	0.002
Falls incidents	0	2	0	0.19
Postoperative complications	1	2	2	0.89
Patient cooperation on POD 1 (%subjects)	87.50	77.80	80	0.83

M = median; POD = postoperative·day; SD = standard deviation
*$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$.

randomized controlled trial[27] reported variations in opiate consumption within the first 12 hours after surgery, it was not included in the review. Conversely, a 2022 meta-analysis[11] indicated that IAB reduced opiate consumption within the initial 24 hours postsurgery compared with FNB. Owing to differences in measurement periods and methodologies, direct comparisons between our study and these previous findings present challenge.

Notable differences arose among the three groups concerning hospitalization duration, with the IAB group having a longer stay. This variance was attributed to hospital policy rather than the choice of nerve block. A 2022 meta-analysis[11] found no differences in hospitalization between FNB and IAB groups. We also noted variations in surgical duration, particularly in the IAB group, but previous reviews have not thoroughly examined surgical duration, and consensus is lacking. We identified variations in the length of surgery between the groups, with the IAB group experiencing more prolonged procedures. Importantly, recent reviews and meta-analyses have not thoroughly examined the variable of surgical duration. Although a 2013[28] study found no differences, a 2017 study[14] reported shorter surgery times with IAB than FNB. The literature lacks a consensus regarding the effect of blocking techniques on surgical duration.

In this study, quadriceps strength was assessed on days 1 and 3/4 after surgery. No notable differences were observed among the three groups. These results align with a 2016 meta-analysis,[25] reporting consistent strength within the initial three postoperative days between FNB and IAB. Notably, the meta-analysis focused on one study with a different blocking

Table 7. **Multiple Regression Analysis of Variables Predicting the Results of Functional Tests After Knee Replacement**

Variable	TUG POD 1 *B*	TUG POD 1 *SE B*	TUG POD 1 β	TUG POD 3/4 *B*	TUG POD 3/4 *SE B*	TUG POD 3/4 β	EMS POD 1 *B*	EMS POD 1 *SE B*	EMS POD 1 β	EMS2 POD 3/4 *B*	EMS2 POD 3/4 *SE B*	EMS2 POD 3/4 β
FNB versus control	26.50	25.15	0.17	46.54	14.15	0.46	0.46	1.32	0.06	−2.20	1.17	−0.27
IAB versus control	16.16	25.40	0.11	12.90	14.39	0.13	−0.17	1.38	−0.02	−0.41	1.17	−0.05
Age	1.13	1.73	0.1	1.07	0.94	0.15	−0.09	0.09	−0.14	−0.05	0.07	−0.08
Preoperative quadriceps strength	−5.69	1.79	0.52	−1.19	0.82	−0.31	0.29	0.09	0.48	0.20	0.07	0.40
OKS	−2.31	1.52	−0.25	0.16-	0.73	−0.03	0.12	0.07	0.26	−0.03	0.06	−0.07
R^2		0.25			0.31			0.24			0.28	
F		2.44			3.98			2.46			3.35	

EMS = Elderly Mobility Scale, FNB = femoral nerve block; IAB = intra-articular block; OKS = Oxford Knee Score; POD = postoperative day; TUG = timed up and go
*$P \leq 0.05$, **$P \leq 0.01$

technique. Conversely, a 2017 study[14] noted early quadriceps strength differences, but had varying patient demographics and less precise measurements. Moreover, incomplete strength data hindered direct comparisons.

This study marks the initial exploration of various factors predicting patient function within the realm of functional assessments, coupled with an investigation into the potential predictive utility of pain blocks. Preoperative quadriceps muscle strength was discerned as a pivotal predictor of patient functionality in both the TUG and EMS tests. Conversely, significance was not ascribed to patient age and preoperative functional status as predictive variables for early postoperative functional outcomes. Furthermore, a predictive relationship was observed between femoral block administration and improved TUG test results on days 3 and 4 after surgery.

By contrast, a previous study conducted by Maiorano et al in 2016[29] identified preoperative functional indices and even younger age, especially among female patients, as predictive factors for early postoperative improvement. However, it is essential to acknowledge that this earlier study used a different index and lacked specificity regarding knee function, rendering direct comparisons with our study challenging. On the other hand, Mizner et al[30] demonstrated the pre-eminence of quadriceps muscle strength in predicting functional measures during the initial postsurgery year. These findings underscore the importance of preoperative quadriceps muscle strengthening, irrespective of the chosen pain block method. The findings of this study contribute markedly to the growing body of evidence highlighting the critical role of preoperative quadriceps muscle strength and its effect on early postoperative function after TKA, regardless of the choice of analgesic method during surgery. Prioritizing the enhancement of preoperative quadriceps muscle strength in TKA patients can substantially enhance their immediate postoperative functional outcomes.

Considering both our study's results and those from Lychagin et al,[27] which showed no notable differences between pain block groups and a control group, questions arise concerning the advantages of using pain blocks in knee replacement surgeries. Although rare, the potential complications associated with nerve blocks further emphasize the need for a critical examination of their utility. However, it is important to acknowledge that the choice of blocking technique should also consider individual patient characteristics and the surgeon's preferences. Our study does have some limitations. Randomization was not feasible due to patient assignments within our orthopaedic department. In addition, involving multiple physical therapists in patient care may have introduced variability in the results. The timing of the second postoperative assessment displayed inconsistencies, occurring between the third and 4th day after surgery. Notably, the FNB group had more day 4 assessments ($P < 0.01$), which could influence TUG test results during the second assessment. However, timing disparities were analyzed, revealing no statistically significant influence on TUG test outcomes within each group, regardless of whether patients were assessed on the third or 4th day after surgery.

Additional longitudinal investigations involving TKA patients with various pain management approaches and those without intervention are imperative to understand the efficacy of pain management strategies. Such studies will offer valuable insights into the long-term effect of pain management modalities on patient rehabilitation. In addition, our findings underscore the potential value of investigating the effectiveness of a pre-TKA rehabilitation program in strengthening the quadriceps muscle. Future research in this direction could markedly enhance overall TKA patient care and recovery.

In summary, our study revealed that among TKA patients, no notable differences in functional outcomes, pain levels, or quadriceps muscle strength were observed between FNB and IAB techniques compared with the control group during the early postoperative period, except for early mobility assessed through the TUG test on POD 3 and 4. Notably, preoperative quadriceps muscle strength emerged as a significant predictor of early post-TKA functional performance, whereas patient age and preoperative functional status did not markedly predict outcomes. Furthermore, FNB demonstrated an advantage in improving TUG test outcomes on POD 3/4.

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