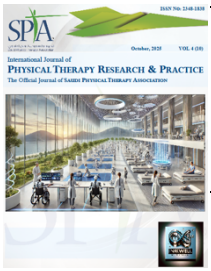

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Original Article

Functional Outcomes After Bilateral Versus Unilateral Total Knee Arthroplasty: A Retrospective Cohort Study in Saudi Arabia

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Abstract

Background: Osteoarthritis (OA) is a chronic degenerative joint disease that often leads to pain, stiffness, and functional disability. Total Knee Arthroplasty (TKA) remains the most effective surgical treatment for end-stage OA. This study aimed to compare the clinical and functional outcomes of patients undergoing unilateral and bilateral TKA in a tertiary rehabilitation setting in Saudi Arabia.

Methods: This retrospective cohort study included 265 patients (≥35 years; both sexes) who underwent primary TKA at Sultan Bin Abdualziz Humanitartian City (SBAHC) Between 2016 and 2020. Clinical and functional data—including pain intensity (Visual Analog Scale), range of motion (goniometric assessment), muscle strength (Manual Muscle Testing), and functional independence (Functional Independence Measure, FIM)—were extracted from medical records at three time points: preoperatively, before discharge, and 3–6 months post-discharge.

Results: The mean age of the patients was 67.1 ± 8.0 years, with females comprising 66.8%. Postoperatively, there was a significant reduction in pain scores ($p < 0.001$) and improvement in knee flexion and extension ($p < 0.001$). Muscle strength and FIM scores improved significantly across all patients, irrespective of age, gender, or postoperative complications. The percentage improvement in total FIM was greater in unilateral TKA patients (63.9%) compared with bilateral TKA patients (48.7%).

Conclusions: Both unilateral and bilateral TKA patients demonstrated significant improvements in pain, joint mobility, muscle strength, and functional independence following a high-intensity rehabilitation program, with greater functional gains observed among unilateral TKA patients.

Keywords: Total knee arthroplasty, Bilateral TKA, Unilateral TKA, Rehabilitation, Functional outcomes, Range of motion.

Introduction

Osteoarthritis (OA) is a prevalent chronic degenerative joint disorder and a major cause of disability worldwide. According to the World Health Organization's 2019 report, OA affects approximately 528 million people globally (Vos et al., 2012; Negrini, 2019). It imposes a substantial and growing economic and social burden on individuals and healthcare systems (Hunter et al., 2014). Among all OA types, knee osteoarthritis (KOA) is the most common, accounting for nearly 85% of the global OA burden (Vos et al., 2016). Despite advances in conservative management, there is currently no curative treatment for KOA, and symptoms typically progress over time, leading to chronic pain, joint stiffness, and functional disability (Litwic et al., 2013). For patients with end-stage disease, Total Knee Arthroplasty (TKA) remains the most effective and widely accepted surgical intervention, offering substantial improvements in pain relief, joint mobility, and quality of life (Santaguida et al., 2008; NIH Consensus Statement, 2003). Moreover, TKA has been demonstrated to be a cost-effective procedure that reduces long-term disability and enhances postoperative functional independence (Chen et al., 2021).

A large proportion of patients with advanced OA are present with bilateral knee involvement. As reported by Ritter et al. (2003), the number of patients requiring bilateral TKA often exceeds those undergoing unilateral procedures. However, there is ongoing debate regarding the relative safety, efficacy, and functional recovery associated with unilateral versus simultaneous bilateral TKA. Some studies have shown better early outcomes and fewer complications with unilateral TKA (Ritter & Harty, 2004; Fu et al., 2013), while others found no significant difference in postoperative function or complication rates (Restrepo et al., 2007; Xu et al., 2019). Conversely, certain studies have reported more rapid functional gains and patient satisfaction with simultaneous bilateral procedures (Iorio et al., 2000; Artz et al., 2015). Total knee arthroplasty is routinely performed to relieve pain associated with knee OA. The goal of rehabilitation after orthopedic surgery is to restore muscle strength, joint stability, and neuromuscular control. Therefore, proper rehabilitation can affect the postoperative course and final results (Mistry et al., 2016). Despite this fact, to date, there are not internationally accepted or commonly agreed and implemented clinical protocols to reliably determine optimal rehabilitation after TKA, and there is much debate on the subject.

Added to this is the scarcity and heterogeneity of most of the research examining the role of physical therapy after TKA (Oatis., 2014; Vajapey et al, 2020; Mutsuzaki et al., 2017). Functional outcomes following TKA are influenced by several factors, including age, sex, comorbidities, surgical technique, and the intensity of postoperative rehabilitation (Jiang et al., 2017). Evidence suggests that early and intensive rehabilitation plays a pivotal role in accelerating recovery and improving long-term outcomes. However, much of the available data comes from Western populations, with limited evidence from Middle Eastern settings where patient demographics, rehabilitation resources, and cultural factors may differ.

In the Saudi community, chronic arthritis of the knee is one of the conditions commonly seen in both genders and old age, especially osteoarthritis which is usually relate to many predisposing conditions. The incidence of OA in the Kingdom of Saudi Arabia is 60% (Young et al., 2009) and its treatment is most commonly sought as TKA surgery. In recent years, the utilization of TKA has

increased markedly in the Kingdom of Saudi Arabia due to rising life expectancy and obesity rates (Alzahrani et al., 2020), with more than 100,000 Saudi patients who are in current need of or will be shortly in need for unilateral or bilateral knee replacement (Papalia et al., 2013). Despite this fact, research addressing comparative functional outcomes after unilateral versus bilateral TKA remains scarce in KSA. Therefore, this study aimed to assess and compare the clinical and functional outcomes of patients undergoing unilateral and bilateral TKA in a large tertiary rehabilitation setting in Saudi Arabia.

Methodology

Study design and setting

This is a retrospective cohort study that assessed patients who underwent total knee replacement in SBAHC during the period from 2016 to 2020. SBAHC is a tertiary rehabilitation institution that has started knee arthroplasty since 2005. Since 2016, SBAHC had adopted medical subvastus surgical approach using Attune for unilateral total knee replacement and press fit condylar (PFC) total knee system for bilateral total knee replacement that have been found to have better surgical outcomes and less side effects and complications. Patients are enrolled in pre- and post-surgical rehabilitation programs that would support a clear pathway for knee replacement in the city.

Study sampling

A total of 1883 patients were hosted by SBAHC for either unilateral or bilateral knee replacement during the period from 2016 to 2020, of which 1500 patients had complete demographic and clinical data. A total of 1300 patients met the following inclusion criteria: being male or female patients aged ≥35 years who underwent unilateral or bilateral primary total knee arthroplasty. Patients who were suffering from neurological diseases, cardiovascular diseases, or any condition that precludes participation in aerobic exercises as indicated by the Physical Activity Readiness Survey were excluded. Patients who were referred to revision arthroplasty or patients who were operated using an arthroscopic approach were also excluded. To reach a sample size of 265 patients, every fifth patient was then selected to maintain the proportional allocation of the study years.

Data collection

Demographic data including age, gender, and marital status were collected from the patient's medical files in a pre-designed case report form. Anthropometric measurements, past clinical history, and comorbidity-related data were also collected. The main indication for TKA was reported. The functional outcome measures that were collected included level of pain, muscle strength, range of motion (ROM), and the functional independence measurement score (FIM Score) [14]. All assessments were conducted by licensed physiotherapists trained in standardized measurement procedures to ensure inter-rater reliability. Based on the patients' electronic files, the surgical reports indicated that all the studied cohorts have been admitted and passed through the routine surgical standard preoperative, intra-operative, and post-operative care.

Attune Total knee system prosthesis (Johnson and Johnson company) was used in unilateral TKA cases, while PFC (SEGMA) Total knee system (Johnson and Johnson company) was used in bilateral TKA cases. All patients were operated using the medial subvastus approach. Tourniquets were used for all patients. Patients received a physiotherapy program postoperatively and during

the period from 3 months to 6 months after discharge.

Within 24 hours of the operation, if recommended by the operating surgeon or his designee, continuous Passive Motion (CPM) was used to maintain knee Range of Motion in addition to the patient's physical therapy and ambulation training for 1 hour. If pain permits, the range of motion is gradually raised to =0° to 90°. The ROM exercises included passive knee flexion and extension, heel slides, active assisted knee flexion/extension in sitting, and ankle pumps. The strength exercise included quad sets, glut sets, hamstring sets, straight leg raises (SLR), emphasizing no lag, hip abduction/adduction, long arc quads (LAQ), and seated hip flexion. Th functional mobility included bed mobility, transfer training, gait training on level surfaces, stair training, activities of daily living with adaptive equipment (as needed). All the exercises are recommended to be performed 3-5 times a day. The progression of therapeutic exercise and functional mobility would remain till the discharge. Post discharge stretching and strengthen exercises that aimed to achieve normal ROM, joint mobilization, and maximum functional outcomes were performed.

The ROM data reported were collected from physiotherapists' notes. The knee flexion ROM was measured as the maximal active bending of the knee with the patient in the supine position. Knee extension ROM was measured as the angle of maximal active straightening with the patient's heel propped on a 10-cm wooden block. The Knee range of motion is measured in degrees of flexion, where a fully extended knee will measure 0º of flexion, while a fully bent knee will measure 135º of flexion. Range-of-motion of the knee was measured in two instances: preoperatively and postoperative.

Tools for assessment

All patients were subjected to the visual analog scale, Medical Research Council's scale (MRC scale), and FIM Score preoperatively, postoperatively before discharge, and 3 to 6 months after discharge.

Visual Analog Scale

The level of pain was reported by reviewing the pre-operative and post-operative pain assessment flowsheets. The level of pain in the hospital is routinely assessed through the visual analog scale (VAS) for pain (VAS pain; 0-10 mm), which was designed to assess the perceived discomfort (0: no discomfort, 10: maximum discomfort) (Delgado et al., 2018).

Medical Research Council's scale (MRC scale)

Muscle strength grades were collected from physiotherapists' notes, where the muscle strength is graded from zero to five using the Medical Research Council's scale (MRC scale), where Zero means no contraction, one indicates flicker or trace of contraction, two denotes the existence of active movement, three means active movement against gravity, four indicates active movement against gravity and manual resistance, and five is used for normal strength (Paternostro-Sluga et al., 2008).

The functional independence measurement score (FIM Score)

The functional independence of the studied cohort was assessed using FIM Score at admission (preoperatively) and discharge (postoperatively). The FIM instrument contains 18 items classified into six major scales: self-care, sphincter control, transfer, locomotion, communication, and social cognition. On each item, each patient rated their level of independence using a 1–7 scale, on which 1

means assistance was needed, and 7 means a person was entirely independent.

Statistical analysis

Data were analyzed using IBM's Statistical Packages for Social Sciences version 25 (SPSS) (IBM Corp., Armonk, NY). Numerical variables were presented as mean and standard deviation. Categorical were presented as frequency and percentage. The outcome was compared in both groups by using the chi-square test. Data were stratified for age, gender, and body mass index. Post-stratification, the outcome was compared in both groups by using a chi-square test for each stratum. Means of pain scores, ROM and other continuous variables were compared based on the normality of data either by ANOVA testing or independent t- test if the data were normally distributed or by alternatives tests for skewed data i.e., Kruskal Wallis, or Mann-Whitney tests. The missing data were handled by imputation. The *P*-value (two-tailed) at ≤0.05 was recognized as significant.

Results

Baseline characteristics

bilateral knee replacement, while 105 (39.62%) had unilateral surgery. Out of the total patients who received surgery in this cohort, 125 (47.17%) lost follow up, while 140 (52.83%) had attended their post-surgical visits and all rehabilitation sessions. Out of which 62 (44.29%) patients had unilateral total knee replacement, while 78 (55.71%) patients had bilateral surgery as shown in Figure 1.

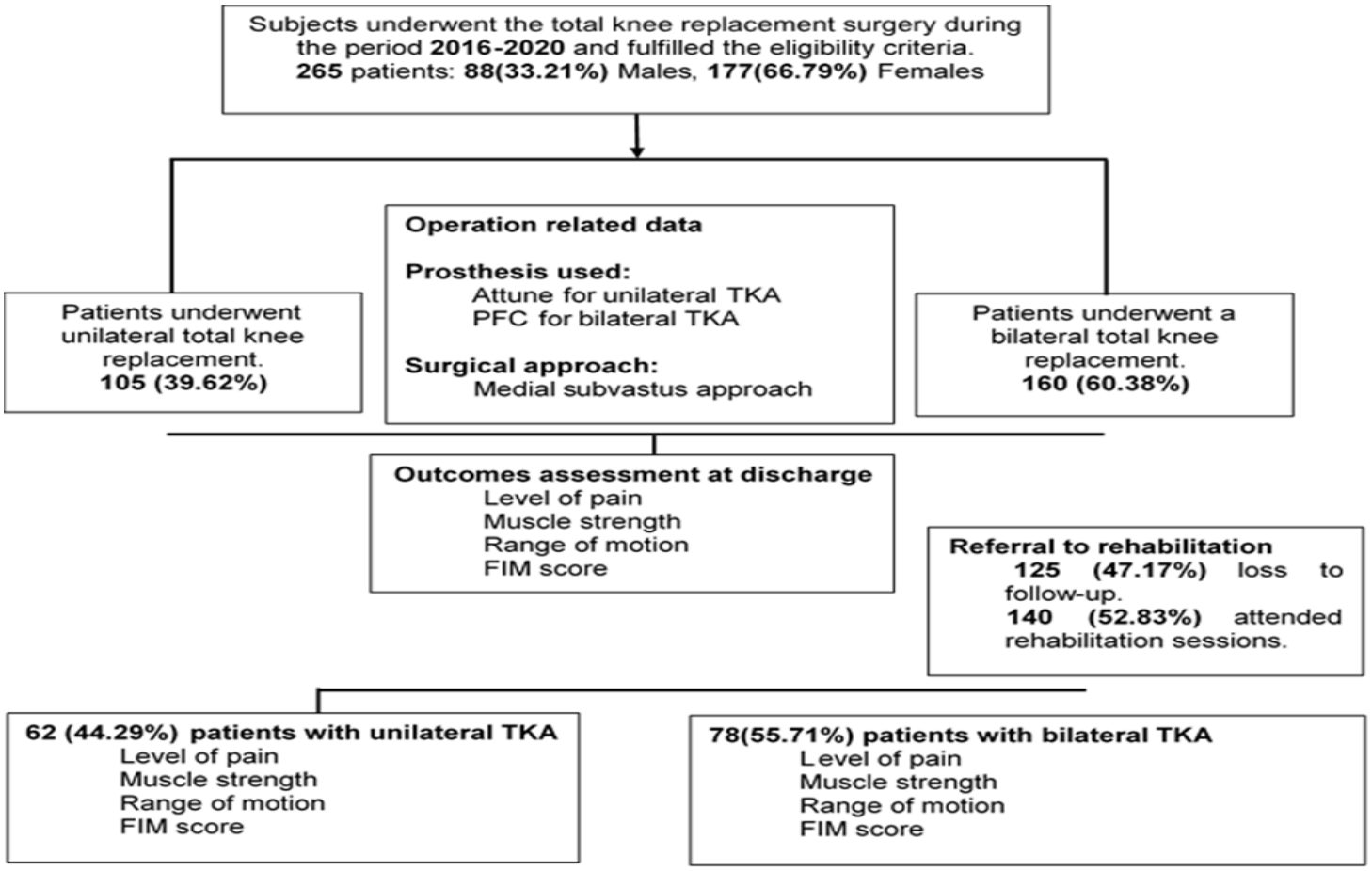

Figure 1. Study Flow chart

Table 1. Baseline characteristics of the studied patients according to the site of the surgery.

Variables		Total n= 265	Unilateral n= 105	Bilateral n= 160	P-value
Number (%)		265	105 (39.62)	160 (60.38)	<0.001
Age (years), mean (SD)		67.09(8.05)	66.37(8.32)	67.57(7.87)	0.24
BMI (kg/m^2) mean (SD)		34.22(6.04)	35.11(6.46)	33.63(5.69)	0.05
BMI category	<24.9 (normal weight)	13 (4.91)	1 (0.95)	12 (7.5)	0.01
	25-29.9 (Overweight)	56 (21.13)	23 (21.90)	33 (20.63)	0.8
	≥ 30 (Obese)	196 (73.96)	81 (77.14)	115 (71.88)	0.34
Gender	Male n (%)	88 (33.21)	33 (37.5)	55 (62.5)	0.24
	Female n (%)	177 (66.79)	72 (40.7)	105 (59.3)	0.16
Marital status	Single n (%)	24 (9.06)	12 (50.0)	12 (50.0)	0.21
	Married n (%)	151 (56.98)	65 (43.0)	86 (57.0)	0.29
	Others n (%)	90 (34.72)	28 (31.1)	62 (68.2)	0.02
Indication of the surgery	Knee pain n (%)	265 (100)	105 (39.62)	160 (60.38)	<0.001
	Radiological changes n (%)	256 (96.60)	102 (39.84)	154 (60.16)	<0.001
	Knee joint-related subjective suffering n (%)	186 (70.19)	73 (39.25)	113 (60.75)	0
	Secondary criteria n (%) Underwent Rehab n (%)	84 (31.70)	15 (17.86)	69 (82.14)	<0.001
Comorbidities	Diabetes Mellitus n(%)	113 (42.64)	43 (38.1)	70 (61.9)	0.6
	Osteoarthritis n (%)	265 (100)	105 (39.6)	160 (60.4)	0.03
Biochemical Characteristics Mean (SD)	Mean Hb	11.85(1.64)	11.62(1.20)	12.01(1.86)	0.63
	Mean WBC	9.06(3.01)	9.50(2.82	8.78(3.10)	0.41
	Mean Platelet	270.7 (98.43)	265.98(97.73	273.79 (99.07	0.29
	Mean RBS	6.97 (2.37)	7.01 (2.03)	6.93 (2.64)	0.75
	Mean HbA1c	6.69 (1.19)	6.61 (1.07)	6.70 (1.27)	0.45
	Mean urea	5.02 (1.94)	5.02 (2.24)	5.03 (1.72)	0.86
	Mean creatinine	63.5 (18.83)	64.79(19.77)	62.67 (18.22)	0.06
	Mean Na	138.55(8.64)	136.7(12.76)	139.75 (3.7)	0.02
	Mean K	4.18(2.33)	3.95 (0.40)	4.32 (2.97)	0.06
	Mean Albumin	40.53(3.72)	40.86 (4.09)	40.32 (3.46)	0.23
	Mean ALT	29.27(17.50)	27.22(13.46)	30.61 (19.63)	0.21
	Mean AST	24.41(11.35)	27.22(13.47)	23.65 (8.24)	0.11
	Mean ALP	84.62(31.19)	82.41(23.53)	86.05 (35.28)	0.5
	Mean GGT	28.77(35.88)	25.78(17.16)	30.69 (43.84)	0.17

As shown in Table 1, the mean age of the study cohort was 67.09 (8.04%) years of which 88(33.21%) were males and 177 (66.79%) were females. The mean BMI was 34.22 (6.03) kg/m^2

being significantly higher in the unilateral group.

The main indication for surgery was knee pain in all cases, especially among patients who had bilateral TKA. This was followed by radiological changes which were significantly present when comparing unilateral with bilateral knee replacement. Knee joint related subjective suffering was observed in two thirds of the cases, mainly bilateral cases. All patients had been found to have osteoarthritis regardless of the type of surgery.

Pain Score before and after the surgery

Table 2 summarizes the mean pain scores pre and post TKA. The mean pain scores were significantly reduced post-operatively compared with the pre-operative scores with different genders, age groups, types of procedures, and pre-existing comorbidities. Overall, the mean pre-operative pain score for all patients was 9.41 (1.75) whereas the post-operative score was 4.37 (1.82) with a *P* value of <0.001 indicating a significant difference. Categorically, a significant difference of mean scores was observed in the pre and post TKA pain scores within and between the following categories: gender, age category, unilateral or bilateral TKA and the presence of DM. This was indicated by a *P* value of <0.001 in all cases.

Table 2. Pain score before and after TKA

Variable		Pain score (Mean (SD)		Mean difference (95 % CI)	P value
		Pre-operative	Post-operative		
Total		9.41 (1.75)	4.37 (1.82)	5.04 (4.74 to 5.34)	**<0.001**
Gender	Male (Reference)	9.50 (1.62)	3.73 (1.77)	5.77 (5.33 to 6.21)	**<0.001**
	Female	9.36 (1.81)	4.69 (1.76)	4.67 (4.21 to 5.13)	**<0.001**
	P Value	**0.287**	**<0.001**		
Age (years) Categories	40-60(Reference)	9.45 (1.58)	4.33 (1.80)	5.12 (4.53 to 5.71)	**<0.001**
	61-80	9.37 (1.83)	4.38 (1.82)	4.99 (4.38 to 5.60)	**<0.001**
	>80	9.80 (0.77)	4.33 (1.99)	5.47 (4.97 to 5.97)	**<0.001**
	P. Value	**0.606**	**0.976**		
Type of procedure	Unilateral TKA	9.40 (1.50)	4.29 (1.99)	5.11 (4.66 to 5.56)	**<0.001**
	Bilateral TKA	9.41 (1.90)	4.43 (1.70)	4.99 (4.53 to 5.43)	**<0.001**
	P. Value	**0.459**	**0.519**		
Comorbidities Diabetes Mellitus	Yes	9.39 (1.79)	4.42 (1.85)	4.97 (4.52 to 5.42)	**<0.001**
	N	9.42 (1.73)	4.34 (1.81)	5.09 (4.65 to 5.51)	**<0.001**
	P. Value	**0.628**	**0.598**		

Outcome measures

Among patients who underwent unilateral TKA, the extension degree for the right knee significantly improved from 55.68 (2.94) º pre-operatively to 2.60 (3.20º) after receiving rehabilitation sessions, however this change was not significant. Flexion degree for right limb increased significantly from 105.91(16.22) º pre-operatively to 111.01 (30.08 º) during the follow-up. This was also true for the

degrees of extension and flexion of the left knee. Among patients who underwent bilateral TKA, the extension degree for the right knee improved from 5.03 (3.82º) pre-operatively to 31.08 (49.99) º after receiving rehabilitation sessions, but non-significantly. Additionally, the flexion degree decreased from 103.08 (18.48) º pre-operatively to 97.50 (49.68) º during the follow-up, this too non-significantly. Additionally, the flexion degree increased significantly from 102.97 (18.48) º pre-operatively to 115.3 (20.04) º during the follow-up. However, for Left Knee Unilateral TKA, despite an improvement in value and degrees, no significant difference was observed for knee flexion and extension categories. The muscle power increased significantly for both the right and left knees regardless of the laterality as shown in Table 3.

Table 3. Pre-operative, post-operative, and follow-up outcome measures after three months and 36 rehabilitation sessions.

Type of surgery		Number	Knee extension degree	Knee flexion degree	Muscle power right	Muscle power left
Right TKA (total unilateral 105)	Admission	44 (41.90)	5.68 (2.94)	105.91(16.22)	3.02(0.26)	3.07(0.25)
	Discharge	44 (41.90)	2.50 (5.00)	119.88 (19.49)	3.97(0.15)	3.95(0.21)
	Follow up (total admission 44)	25 (56.81)	2.60 (3.20)	111.01 (30.08)	3.00(0.00)	3.33(0.51)
ANNOVA			**0.00**	**<0.001**	**<0.001**	**<0.001**
Left TKA (total unilateral 105)	Admission	61 (58.09)	5.42 (3.17)	102.21 (20.88)	3.15 (0.40)	2.98 (0.31)
	Discharge	61 (58.09)	7.00 (4.58)	123.11 (23.50)	3.97 (0.18)	3.93 (0.31)
	Follow up	37 (60.65)	1.29 (1.70)	106.67 (24.22)	3.57 (0.53)	3.38 (0.52)
ANNOVA			**0.00**	**0.03**	**<0.001**	**<0.001**
Bilateral Right (total bilateral 160)	Admission	160 (100)	5.03(3.82)	103.08 (18.48)	3.03(0.37)	2.99(0.27)
	Discharge	160 (100)	6.08(5.35)	118.14 (19.17)	3.97(0.26)	3.97(0.24)
	Follow up (Total admission 160)	78 (48.75)	31.08(49.99)	97.50 (49.68)	3.67(0.49)	3.76(0.46)
ANNOVA			**0.15**	**0.00**	**<0.001**	**<0.001**
Bilateral Left (total bilateral 160)	Admission	160 (100)	4.78(3.37)	99.55 (13.80)	3.03 (0.37)	2.99 (0.27)
	Discharge	160 (100)	5.30(4.83)	99.15 (44.39)	3.95 (0.26)	3.97 (0.24)
	Follow up	78 (48.75)	21.77(42.97)	116.0 (10.81)	3.67 (0.49)	3.75 (0.46)
ANNOVA			**0.72**	**0.17**	**<0.001**	**<0.001**

*Muscle power is overall right and left, irrespective of laterality. Only 161 (60.75%) patients out of the total studied sample attended the rehabilitation sessions.

Postoperative change according to age, gender, and existing co-morbidities

As shown in Table 4, the mean flexion degree for the right knee and left knees decreased after surgery significantly for both genders, DM patients, patients with Rheumatological disorders and Osteoarthritis cases. However, in age categories, the values for ROM improved significantly after surgery for both knees with the exception of the category of >80 years, where an insignificant decrease was observed for the Right knee from 5.33 (2.97) to 2.07 (4.6). A maximum mean difference in ROM knee flexion of 4.37º was seen for the right knee and 5.00 º for the left knee.

The mean ROM right knee extension degree was 99.21 (11.17) º preoperatively for females, while the lowest was among males at 100.0 (9.74) which increased pos-operatively to 90.17 (9.49) º with a mean change of 9.83(7.33 to 12.33). For extension, all ROM changes for the right knee pre and post operatively were significant except for the age category of >80 years. However, for the left side, all changes in ROM pre and post TKA were insignificant except for one category of Osteoarthritis patients as shown in Table 4.

Table 4: Preoperative and postoperative change in knee flexion and Extension Range of Motion for patients undergoing TKA according to age, gender, and existing co-morbidities.

Variable	ROM (Right)		Mean difference (95 % CI)	P value	ROM (Left)		Mean Difference (95 % CI)	P value
	Before	After			Before	After		
FLEXION								
Gender Male (88)	5.35 (2.49)	1.68 (3.89)	4.12 (3.27 to 4.95)	<0.001	5.64 (2.49)	1.63 (4.23)	4.17 (3.35 to 4.99)	<0.001
Female (177)	5.17 (3.63)	0.81 (2.79)	4.37 (3.72 to 5.01)	<0.001	4.97 (2.59)	0.81 (2.78)	4.17 (3.64 to 4.69)	<0.001
Age 40-60(42) (REF)	4.88 (2.59)	1.19 (3.46)	3.69 (2.45 to 4.93)	<0.001	5.48 (1.85)	0.83 (3.30)	4.64 (3.77 to 5.51)	<0.001
61-80 (208)	5.30 (3.45)	1.01 (3.05)	4.29 (3.69 to 4.89)	<0.001	5.10 (3.03)	1.15 (3.40)	3.94 (3.40 to 4.49)	<0.001
>80 (15)	5.33 (2.97)	2.07 (4.61)	3.26 (0.34 to 6.19)	0.031	5.71 (1.82)	0.71 (2.67)	5.00 (3.87 to 6.13)	<0.001
Diabetes Mellitus (113)	5.19 (3.22)	1.44 (3.60)	3.75 (2.87 to 4.63)	<0.001	5.36 (2.89)	1.35 (3.46)	4.01 (3.25 to 4.76)	<0.001
Rheumatological (113)	5.19 (3.31)	1.10 (3.22)	4.09 (3.29 to 4.89)	<0.001	5.21 (2.83)	1.08 (3.35)	4.13 (3.36 to 4.90)	<0.001
Osteoarthritis (265)	5.23 (3.29)	1.10 (3.22)	4.13 (3.60 to 4.66)	<0.001	5.19 (2.82)	1.08 (3.35)	4.11 (3.66 to 4.57)	<0.001
EXTENSION								
Gender Male (88)	100.0 (9.74)	90.17 (9.49)	9.83 (7.33 to 12.33)	<0.001	93.89 (10.45)	91.1 (9.09)	2.72 (0.22 to 5.24)	0.033
Female (177)	99.21 (11.17)	90.94 (12.54)	8.27 (5.88 to 10.86)	<0.001	94.08 (10.39)	91.30 (9.72)	2.79 (0.81 to 4.76)	0.006
Age 40-60(42)	99.52	89.33	10.19(6.31	<0.001	92.88	89.38	3.50 (0.82 to	0.012

(REF)	(10.29)	(8.42)	to 14.1)		(7.27)	(5.89)	6.18)	
61-80 (208)	99.47 (10.91)	90.97 (12.23)	8.50 (6.44 to 10.56)	<0.001	94.41 (11.12)	91.65 (10.23)	2.76 (0.89 to 2.91)	0.004
>80 (15)	99.33 (9.61)	90.47 (10.71)	8.87(-0.71 to 18.45)	0.067	91.73 (5.09)	91.00 (6.32)	0.73 (-4.97 to 6.43)	0.787
Diabetes Mellitus (113)	99.34 (10.60)	90.03 (12.10)	9.31(6.58 to 12.04)	<0.001	94.33 (10.89)	91.68 (9.89)	2.64 (0.16 to 5.14)	0.037
Rheumatological (113)	90.68 (11.61)	99.47 (10.71)	-8.79(-11.51 to -6.07)	<0.001	91.25 (9.50)	94.02 (10.39)	2.77 (0.32 to 5.22)	0.00
Osteoarthritis (265)	99.47 (10.71)	90.68 (11.61)	8.79(6.99 to 10.58)	<0.001	94.02 (10.39)	91.25 (9.5)	2.77 (1.21 to 4.32)	<0.001

Postoperative MRC scores according to age, gender, and existing co-morbidities

As summarized in Table 5, the mean MRC score for the right knee improved postoperatively for all patients regardless of age, gender or complications with a mean difference reaching up to an increase 5.51 degrees for males and the MRC of the left side and the highest on the right leg being 1.43 for the age category 40-60 years. The muscle strength improved significantly for the right and left knees pre and post operatively for all categories except for the category of age above 80 years for both left and right limbs, and the left side for OA patients. The improvement in MRC scores from admission to the follow-up (P<0.0001), are shown in Figures 2 A and 2 B.

Table 5: Preoperative and postoperative MRC scale scores in patients with TKA according to age, gender, and existing co-morbidities.

Variable	Total	Muscle power (Right)		P value	Muscle power (Left)		P value
		Pre-operative	Post-operative		Pre-operative	Post-operative	
Male	88	1.19(0.68)	2.60(0.85)	<0.001	1.44(0.90)	6.96(5.38)	<0.001
Female	177	1.39(0.89)	2.56(0.95)	<0.001	1.50(0.96)	5.01(4.52)	<0.001
Age 40-60	42(REF)	1.36(0.85)	2.79(0.75)	<0.001	1.60(1.08)	6.94(5.09)	<0.001
Age 61-80	208	1.30(0.80)	2.54(0.96)	<0.001	1.46(0.91)	5.44(4.81)	<0.001
Age >80	15	1.53(1.13)	2.53(0.74)	0.010	1.4(0.91)	5.15(5.42)	0.016
Diabetes Mellitus	113	1.28(0.78)	2.52(0.90)	<0.001	1.44(0.90)	5.73(4.90)	<0.001
Rheumatological disease	113	1.32(0.83)	2.58(0.92)	<0.001	1.47(0.92)	3.99(3.80)	<0.001
Osteoarthritis	265	1.32(0.83)	2.58(0.92)	<0.001	1.48(0.94)	5.66(4.90)	0.00

MRC scale: Medical Research Council's scale, TKA: Total Knee Replacement

Functional Outcome measures

Concerning the FIM score, there was a significant improvement in all the scales with a total percentage of improvement of 63.87% for patients

who underwent the unilateral TKA and 48.74% for patients who underwent the bilateral TKA. The highest improvement rate was observed in the transfer scale at 59.43% and 48.43% for those who underwent unilateral TKA and those who underwent bilateral TKA respectively, followed by the locomotion scale at 57.79% and 45.14% for those who underwent unilateral TKA and those who underwent bilateral TKA respectively, then the self-care scale at 51.95% and 43.76% for those who underwent unilateral TKA and those who underwent bilateral TKA respectively as shown in Table 6.

Table 6. Functional Outcome measures

FIM Scale Mean (SD)	Admission	Discharge	P	Max Score	Admission (% max score)	Discharge (% max score)	Improvement (%)
Self-care							
Unilateral	10.58(6.93)	32.4 (4.43)	**<0.001**	42	25.19%	77.14%	51.95%
Bilateral	12.36(9.26)	30.74(7.93)	**<0.001**		29.43%	73.19	43.76%
P value	**0.18**	**0.25**					
Sphincter-Control							
Unilateral	8.52±5.11)	13.80(0.53)	**<0.001**	14	60.86%	98.57%	37.71%
Bilateral	8.41 (5.35)	13.06(2.80)	**<0.001**		60.07%	93.29%	33.22%
P value	**0.9**	**0.12**					
Transfer							
Unilateral	2.78 (2.14)	15.26(2.98)	**<0.001**	21	13.24%	72.67%	59.43%
Bilateral	3.51 (3.96)	13.68(4.11)	**<0.001**		16.71	65.14%	48.43%
P value	**0.16**	**0.05**					
Locomotion							
Unilateral	1.77 (1.99)	9.86 (2.46)	**<0.001**	14	12.64%	70.43%	57.79%
Bilateral	2.43 (3.02)	8.75 (2.90)	**<0.001**		17.36%	62.50%	45.14%
P value	**0.25**	**0.06**					
Communication							
Unilateral	10.40(6.21)	13.94(0.34)	**0**	14	74.29%	99.57%	25.28%
Bilateral	10.29(6.16)	13.59(2.38)	**<0.001**		73.50%	97.07%	23.57%
P value	**0.93**	**0.38**					
Social-Cognition							
Unilateral	15.60(9.31)	20.80(1.18)	**0**	21	74.29%	99.05%	24.76%
Bilateral	15.13(9.41)	20.38(3.57)	**<0.001**		72.05%	97.05%	25%
P value	**0.81**	**0.5**					
Total FIM							
Unilateral	18.65(25.68)	99.13(17.00)	**<0.001**	126	14.80%	78.67%	63.87%
Bilateral	36.96(32.20)	98.37(20.95)	**<0.001**		29.33%	78.07%	48.74%
P value	**<0.001**	**0.8**					

Discussion

Total knee arthroplasty (TKA) remains the most effective surgical option for relieving pain and

improving function in patients with end-stage OA. The growing demand for TKA in Saudi Arabia (Papalia et al., 2013), underscores the clinical and public health importance of optimizing outcomes and rehabilitation protocols. Over the last 14 years, (institution name) had received around 1500 cases who had been selected for knee replacement mainly indicated by pain supporting knee replacement based on radiological findings. This study examined and compared functional and clinical outcomes among patients undergoing unilateral and bilateral TKA in a tertiary rehabilitation center, focusing on the effects of intensive postoperative rehabilitation. The mean age and the predominance of the females in the current study is similar to the observation of Davis et al., (Davis et al., 2011). This can perhaps be explained by the higher BMI and obesity in the female group as was also seen in our study's cohort where more than 70% had a BMI ≥ 30 Kg/m2.

Pain Reduction and Functional Gains Our findings demonstrate a significant reduction in pain intensity from a mean preoperative score of 9.41 to a postoperative score of 4.37 and also meaningful ROM improvements. The Functional Independence Measure (FIM) scores improved significantly across all six domains—self-care, mobility, transfer, locomotion, communication, and cognition— In the current study, the rehabilitation sessions were associated with improved quadriceps muscle strength, where the mean MRC scale score increased by more than double at the end of the rehabilitation sessions. This was in line with the findings of Castorina et al (Castorina et al., 2018). This improvement was not limited to the operated limb only, but it was also observed in the contralateral (non-operated) limb. Such finding indicates the effectiveness of the adopted rehabilitation program since it takes into consideration the importance of the quadriceps indicating holistic functional recovery. These findings mirror those of Vincent et al. (2006), who reported a similar upward trajectory in FIM scores from admission to discharge following intensive rehabilitation.

Since pain after TKA could be a limiting factor for postoperative rehabilitation activities, monitoring pain and taking all the measures to alleviate it should be one of the primary targets for the TKA procedure. The postoperative recovery phase offers an important intervention window to prevent the pain from becoming chronic, especially when identifying individuals at high risk for chronic pain preoperatively to take preventive measures is challenging (Wylde et al., 2022). The current study has shown a significant decrease in the pain intensity from preoperative to postoperative follow up period by more than 46% for the overall cohort. This was also reported by observation of Ramlall et al (Ramlall et al., 2019), yet this was not the observation of Miner et al., where 20% of patients reported increased pain post TKA in comparison to pre-operatively (Miner et al., 2003). However, this durable improvement could have resulted from the extensive rehabilitation program provided by (institution name) to the TKA patients postoperatively.

strength in the contralateral limb, where it has been reported as a significant and independent predictor of functional performance (TUG and stair climb tests) 1 and 2 years after TKA (Zeni Jr et al., 2010; Suh et al., 2019).

The improvement in both unilateral (63.9%) and bilateral (48.7%) groups underscores the importance of structured, high-intensity physiotherapy programs that integrate muscle strengthening, mobility training, and balance re-education. Comparative Outcomes of Unilateral and Bilateral TKA The present study found no

clinically significant differences in postoperative pain, muscle strength, or functional independence between unilateral and bilateral TKA groups. These results are consistent with the findings of Bagsby and Pierson (2015), who reported comparable functional outcomes and complication rates between the two procedures. The equivalence in results suggests that, with adequate rehabilitation support, both surgical options can achieve favorable outcomes, allowing clinicians to base the choice of procedure on patient preference, comorbidities, and surgical risk tolerance rather than anticipated functional performance. Interpretation in the Context of the Literature Collectively, these findings reinforce the growing consensus that postoperative rehabilitation intensity is a stronger determinant of functional recovery than the surgical approach itself (Oatis, 2014; Vajapey et al., 2020).

Females, participants older than 60 years, and patients with BMI>30 kg/m^2 showed improved extension ROM at the three months follow-up. The finding that females obtain equivalent, if not better, outcomes than men was reported in a meta-analysis (Xie et al., 2014). This could be attributable to the lower preoperative health-related quality of life in women, thereby women having more to gain from surgery, or may be due to different postoperative activity levels, psychologic factors, or different utilization of treatment (Liebs, et al., 2011). However, this was opposite to the observation of Lim et al., where they reported that females most likely have poorer outcomes compared to males mainly due to the fact that women usually present later than men because of a lack of social support or willingness to undergo surgery (Lim et al., 2015). On the other hand, the flexion ROM was higher in patients who are less than 60 years of age as compared to patients more than 60 years of age. This is in line with the findings of other researchers (Judge et al., 2012) and could be explained by the fact that they mostly have other comorbid conditions that could limit the improvement (Murphy et al., 2018). Despite such differences between the two genders, age groups, and BMI groups in ROM extension and flexion angles were significant in all the groups of patients, the outcomes of the TKA procedures indicated improvement in the functional outcomes, especially for those who completed the 12 weeks rehabilitation sessions. . The improvements across all demographic strata indicate that older age, female gender, and obesity should not be viewed as barriers to effective recovery when structured physiotherapy is available. This observation supports prior conclusions by Santaguida et al., that TKA provides broad functional and quality-of-life benefits irrespective of baseline physical condition. (Santaguida et al., 2008).

Study Limitations

The main limitation of this study is its retrospective design, which restricts causal inference and depends on the completeness and accuracy of medical records. The study was conducted at a single tertiary center and included a modest sample size (n = 265), limiting the generalizability of the findings. Data on rehabilitation adherence, long-term outcomes, and comorbid conditions were not analyzed, which may have influenced the observed functional improvements. Future research should employ prospective, multicenter designs with larger samples to validate these findings, evaluate long-term functional trajectories, and compare different rehabilitation intensities or delivery models (e.g., inpatient vs. home-based). Further investigation into predictive factors—such as psychological readiness, motivation, and social support—may also enhance individualized rehabilitation planning after TKA.

Conclusion

Both unilateral and bilateral total knee arthroplasty resulted in significant improvements in pain reduction, muscle strength, joint mobility, and overall functional independence following a structured, high-intensity rehabilitation program. The benefits were consistent across different patient subgroups, including variations in age, gender, and BMI, indicating that these demographic factors should not preclude surgical eligibility or intensive rehabilitation. Given the strong association between rehabilitation intensity and functional gains, it is recommended that comprehensive, multidisciplinary rehabilitation programs be integrated into standard postoperative care for all TKA patients. Future longitudinal studies are warranted to determine the long-term sustainability of these outcomes and to optimize rehabilitation protocols tailored to individual patient needs.

Author Contributions

All authors significantly contributed to the work reported, including conception, study design, execution, data acquisition, analysis, and interpretation. They actively participated in drafting, revising, or critically reviewing the manuscript, provided final approval of the version to be published, agreed on the journal submission, and accepted accountability for all aspects of the work.

Data Availability Statement

The authors will transparently provide the primary data underpinning the findings or conclusions of this article, without any unjustified reluctance. If need from editorial team.

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