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Sensorimotor versus core stabilization home exercise programs following total knee arthroplasty: a randomized controlled trial

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Abstract

Introduction: Although total knee arthroplasty (TKA) is a frequently-performed surgery, no standard rehabilitation approach has yet been established. The study aimed to compare the effects of sensorimotor and core stabilization exercises on proprioception, range of motion, balance, and function following TKA.
Material and methods: This randomized trial was conducted with 40 female patients (69.38 ± 5.81 years) who had undergone unilateral TKA. The participants were randomly allocated to either a sensorimotor group (N = 20) or a core stabilization group (N = 20). The patients performed exercise programs over a six-week period between the second and eighth weeks postoperatively. Proprioception, knee and hip range of motion, Knee Injury and Osteoarthritis Outcome Scale (KOOS), Berg Balance Scale, Timed Up and Go test, and 5-times sit-to-stand test were measured on three separate occasions: preoperative (E0), before treatment (E1), and after treatment (E2) during postoperative rehabilitation.
Results: Both groups demonstrated statistically significant improvements for all outcomes between E1 and E2 ($p < 0.05$). However, the sensorimotor group exhibited a significantly improvement compared to the stabilisation group regarding KOOS-sportive recreational activities ($p < 0.001$). Additionally, both treatment programs provided recovery of knee and hip ROM and proprioception ($p < 0.05$).
Conclusions: Core stabilization exercises are effective for improving balance, proprioception, function, and ROM; however, sensorimotor exercises are more effective in the acquisition of sports and recreational activities. Both programs provide effective rehabilitation on a bilateral extremity.

Keywords: arthroplasty, functional performance, knee, rehabilitation, replacement

Introduction

Osteoarthritis (OA) is a chronic, progressive degenerative disease leading to pain and limited function in patients [1,2]. OA is the primary cause of joint replacement in 81% of hip and 94% of knee arthroplasty [3,4]. Total knee arthroplasty (TKA) is frequently performed to relieve symptoms and realign joint mechanics [5-7]. However, while TKA is a common procedure, postoperative deficits can potentially constrain functional performance [8]. Previous studies reported dissatisfaction rates as high as 30% among patients five years after surgery [9], and 28.9% of patients had still pain and unsatisfactory functional levels two years after surgery [4]. Therefore, rehabilitation plays a crucial role in the management of potential problems after TKA.

As people age, they typically lose 30-40% of muscle strength and proprioception in the lower extremities. Thus, patients are often subject to instability problems and joint degeneration before surgery [10,11]. Furthermore, following surgery, the restored structures demonstrate impaired sensorimotor function, such as loss of mechanoreceptors, muscle strength, postural instability, and proprioception resulting in an increased risk of falls and a greater tendency to lose postural control after TKA [7,12,13]; indeed, a fall rate of 45% has been reported following rehabilitation, it is thought that this may be due to only partial restoration of the sensorimotor system [14]. Some studies report an increased risk of falls ranging from 17% to 48% following TKA compared to non-operated individuals [15,16]. Another study demonstrated 18% slower walking and 51% slower stair climbing after TKA compared to a healthy group [17]. As such, TKA remains the most common reason for falling and functional limitation [18].

In current clinical practice, TKA rehabilitation incorporates a range of diverse complementary therapies; however, one of the most frequently preferred and evidence-based methods is exercise [19,20]. While it is known that rehabilitation is more effective than non-intervention, it remains unclear which exercise yields the greatest benefits [21]. Among the therapies, sensorimotor training (SMT), or neuromuscular training, is an approach based on a combination of proprioceptive and balance exercises. SMT aims to improve the facilitation of proprioceptors to improve the strength of muscle contraction and regulate correct motor unit response. Balance and muscle strength assessments are used to monitor the future general health status of patients in activities of daily life and their risk of mortality [7]. Although SMT is useful for improving postural stability, muscle strength, balance, and functional status [16,22,23], there is no exact evidence-based approach to exercise [16]. Another exercise-based approach is core stabilization (CS), which can be defined as the ability to maintain structural integrity between the lumbopelvic and hip regions [24]. CS exercises improve static balance, flexibility, stability, quality of function, and proprioceptive input and reduce postural oscillations [25,26]. Therefore, these exercises represent a treatment option for protecting against falls and improving functional performance [27,28]. Although the concept has been frequently used in rehabilitation, especially for low back pain, few trials have demonstrated any clinical effects after TKA [28,29].

However, to date, only limited research has examined the effectiveness of CS on different outcomes after TKA. As such, our present findings are significant as they illustrate the effects of CS on various parameters and compare them with those of SM after TKA. In addition, no previous trials have investigated the effects of training on bilateral lower extremities with regard to different outcomes. In contrast, the present study examines the efficiency of different exercise programs on the non-operated limb. Therefore, its primary objective was to assess the impact of core stabilization and sensorimotor exercise programs on the range of motion, proprioception, balance, and functional performance following TKA. We hypothesize that all outcomes would improve in two groups, but one method would achieve more favourable results than the other.

Materials and methods

Study design

A single-blinded, prospective, and randomized controlled trial was conducted between November 2019 and June 2020 in the Orthopaedics and Traumatology Clinic, Tuzla State Hospital in İstanbul. The study was conducted according to the Helsinki Declaration. Ethical approval for this study was approved by the Research Ethical Committee of Yeditepe University (study protocol: KAEK1030). Written informed consent was signed and obtained from all clients before enrolment. The study protocol was registered at ClinicalTrials.gov (ID: NCT05248854).

After being initially examined and the surgery date was planned, the participants were invited to take part in the study. A therapist explained the purpose, methodology, and potential risks of the trial. All participants who agreed to take part and gave their written consent. All baseline assessments were then performed before surgery. All participants received the same hospitalization care during the postoperative two weeks and were then examined again. All measurements were performed by the same therapist at three time points: at baseline (E0), i.e. before surgery, two weeks postoperatively (E1), i.e. at the beginning of treatment, and then after six weeks of treatment (E2).

Participants

A total of fifty-two patients who were diagnosed with OA and were appropriate for surgery were included in the study. However, six patients did not met inclusion criteria, four patients did not give consent to join the study and two patients did not undergo TKA. Therefore, a total of 40 patients were enrolled. These were divided into two groups based on the treatment programme: sensorimotor (SM, N = 20) and core stabilization (CS, N = 20). Throughout the treatment, in the SM group, one patient was excluded due to moving to another city after the operation, another underwent bilateral total knee arthroplasty, and another had transient ischemic attack symptoms after surgery. Additionally, only one volunteer from the CS group was excluded because of treatment for a prolonged serious infection at the intensive care unit (Figure 1).

The following inclusion criteria were applied: (1) ages between 50 and 75 years, (2) Kellgren Lawrence grade 3-4 knee osteoarthritis, and (3) undergoing unilateral TKA surgery. The following exclusion criteria were applied: (1) previous surgery history of the lower extremities, (2) impaired sensory problems, (3) physical or mental disability or (4) the presence of a neurological or oncological disease that may affect functional performance.

Surgery was performed by the same physician. The three assessments were carried out by a therapist who did not know the treatment groups, and the interventions were given by another therapist. The physician and therapist who assessed the participants were blinded to the interventions.

Study group allocation was performed using a computer software randomization list from https://www.randomizer.org/website. The maximum randomization numeric interval was determined based on the study sample size, and numbers from 1 to 46 were randomly assigned to two groups on the website. Each number was included once, in one of the two groups and the therapist providing the intervention directed the patients to the group appropriate to the number.

Sample size

The sample size was calculated with the PS Power sample size calculator program. Assuming a standard deviation of 2.8, and a minimal clinically-significant change in the Berg Balance Scale of three points, with a 95% confidence interval, at least 19 volunteers should be included in each group to detect the difference at 95% power and 0.05 significance level [9]. Although 38 patients would be sufficient, 20% more were included to account

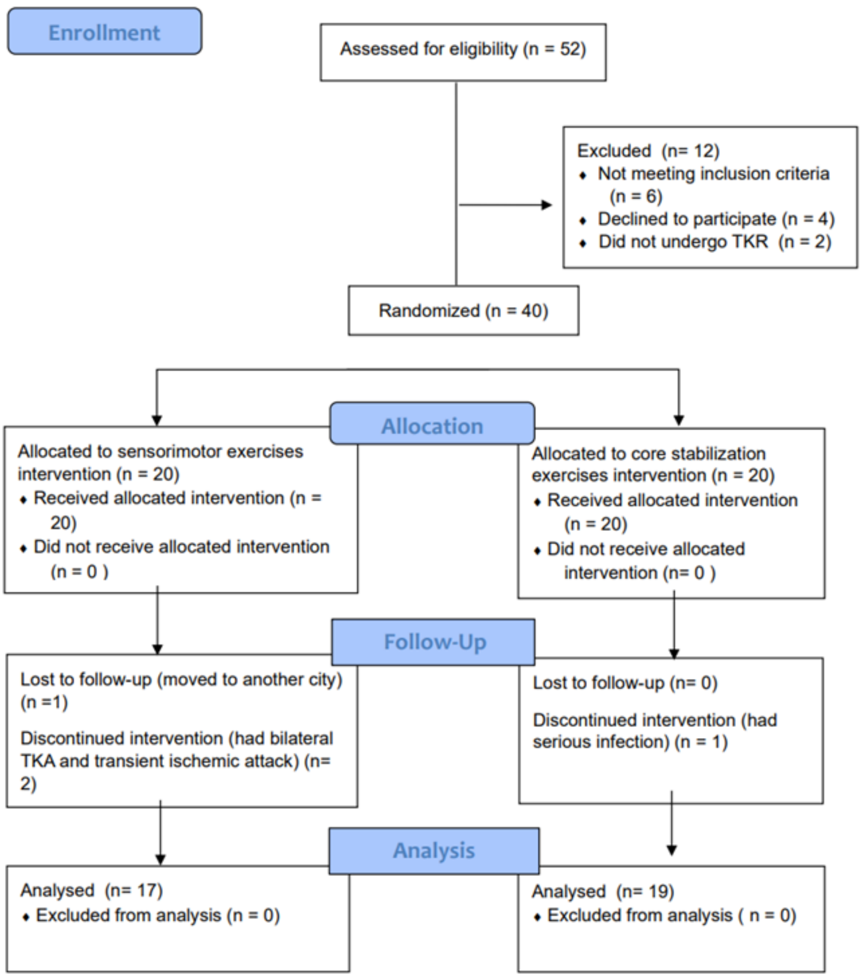

Fig. 1. CONSORT flow chart of the study

for the possibility of dropping out. Therefore, a total of 46 participants were included in the study.

Outcome measures

The primary outcome measure was balance, evaluated with the Berg Balance Scale (BBS); the secondary outcomes were knee joint position sense (JPS), the range of motion (ROM) of the knee and hip joints of bilateral limbs, functional performance and physical evaluation with the Knee Injury and Osteoarthritis Outcome Score (KOOS).

The Berg Balance Scale was used to assess the static balance and fall risk. The scale comprises different tasks scoring between 0-4 points, with a total score between 0-56. A higher score indicates a better balance level [30]. The reliability and validity of the Turkish version have been confirmed [31].

The ROM of the hip and knee joints was evaluated with a universal goniometer. JPS was assessed based on proprioception, which was tested by reproducing the joint angle test [19,32,33]. The test has been previously tested for validity and reliability [34,35]. Briefly, the therapist modelled a target reference of 30° and 60° active knee flexion angles passively three times, starting from a completely extended position; the position was held for 10 seconds, and then the leg was returned to the initial position while sitting. Following this, the client actively attempted to achieve the target angles with their eyes closed for three trials. The deviation means of three trials for 30° and 60° angles were recorded.

The Sit-To-Stand-Up (STS) Test and Timed–Up and Go (TUG) Test were applied to evaluate functional performance, balance and fall risk. The validity and reliability of the tests have been confirmed previously [36,37]. In the STS test, the patients practice sitting and standing up five times as quickly as possible, and the examiner records the elapsed time [36]. In the TUG test, the patient stands up independently from a chair, walks 3 m, turns around a predetermined point, and sits again at the starting point; the total time for the sequence is recorded [37]. The minimum 2.49 seconds difference after treatment exhibits fine clinical significance change, and above 14 seconds during TUG test performance indicates a higher risk of falling [20]. The Turkish version of the tests used in the study have also demonstrated validity and reliability [38].

The KOOS was used to evaluate the functional performance of the knee. The scale contains 42 likert questions with five subtests: pain, symptoms, activities of daily life (ADL), quality of life (QoL), sports, and recreative function (SRF). All questions are scored 0-4 points, a higher point indicates a lack of knee problems. The reliability and validity of Turkish version used in the present study have been confirmed [39].

Intervention

In this two-armed trial, one group received CS and the other SM. The exercise programs were explained to the patients and performed by the therapist, and all participants received written instructions for use at home at the beginning of the treatment. The treatment programs took place between postoperative second and eighth weeks. All participants were asked to perform four 20-minute sessions per week, over six weeks, as a home-based program. The patients were followed up via telephone each week and checked during face-to-face interviews in the postoperative fourth week.

The SM program was based on a combination of traditional strengthening and stretching exercises, various balance and proprioceptive exercises consisting of side-stepping, tandem walking, perturbation exercises with eyes open and closed, overcoming mini obstacles, drawing figures on a single leg, walking on different surfaces, standing on one leg on hard and soft floors without support, and traditional hip and knee strength exercises [11,12,22]. The CS program was based on traditional hip and knee strengthening and stretching exercises combined with core stabilization mat activities. The program consisted of diaphragmatic breathing, abdominal hallowing, pelvic tilt, clam exercise, twist exercise, breast lifting, and dead insect exercise, and was progressively combined with active movement [28,29,32,40]. The program progress was checked during face-to-face interviews during the fourth week. All the organization and methodological description of this trial is given in the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) table in table 1.

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 21.0. The distribution of continuous variables was confirmed visually (histogram, probability graphs), by skewness and kurtosis value, and analytically using the Kolmogorov- Smirnov or Shapiro-Wilk test. As all data conformed to a normal distribution, parametric tests were used in the analyses. Categorical variables were expressed as percentage (%) and the number of people (n), while mean and standard deviation (sd) values were defined for continuous variables. When comparing demographic data, between study groups, an independent samples t-test was used for numerical variables and chi-square analysis was used for categorical data. The parameters were compared with regard to group and time using the 2-by-2 Mixed Model Repeated Measures ANOVA and 2-by-3 Mixed Model Repeated Measures ANOVA. When in determining the effect size between variables, the partial eta squared (ηp^2) value was taken into account; this value is classified as small (0.01), medium (0.06) or large (0.14) [41].

Tab. 1. Content for the schedule of study

	Enrolment	Allocation		
TIMEPOINT**		E0	E1	E2
	ENROLMENT			
Physician examination	X			
Eligibility screen	X			
Informed consent	X			
Allocation		X		
	INTERVENTIONS			
Sensorimotor exercises group			⟷	⟷
Core stabilization exercises group			⟷	⟷
	ASSESSMENTS			
Informed consent form	X			
Demographic information form	X			
Balance evaluation		X	X	X
Joint position sense		X	X	X
Range of motion		X	X	X
Functional performance tests		X	X	X
Physical evaluation		X	X	X

*List of specific timepoints in this row. E0- preoperative evaluation, E1- pretreatment evaluation at second week post-op, E2- post-treatment evaluation at eight weeks post-op

Tab. 2. Baseline characteristics of participants

Variables	**SM (N = 17) mean (SD)**	**CS (N = 19) mean (SD)**	**t**	**p**
Age (years)	69.05 (5.39)	69.68 (6.19)	0.32	0.75
Height (m)	1.58 (0.07)	1.59 (0.7)	-0.17*	0.85
Weight (kg)	84.70 (15.57)	81.88 (9.97)	-0.65	0.51
BMI (kg/m2)	33.54 (5.70)	32.46 (4.73)	-0.62	0.53
TUG (s)	20.40 (5.73)	22.23 (8.43)	0.72	0.47
Sit and Stand-Up Test (s)	21.55 (4.13)	19.77 (4.80)	-1.17	0.24
Berg Balance Test (point)	37.52 (6.96)	39.94 (9.54)	0.85	0.39

BMI- Body Mass Index CS- Core Stabilization group, SD- standard deviation SM- Sensorimotor group, TUG- Timed Up and Go Test, *- z value of Mann Whitney U-test

Results

Fifty-two patients scheduled for TKA were assessed for eligibility. Forty-six patients (N = 46) satisfied the inclusion criteria, and finally 40 participants (N = 40) were randomly assigned to the core stabilization or sensorimotor groups. As four patients dropped out, 36 patients (69.38 ± 5.81 years) completed the treatment (Figure 1). Baseline data were similar in both groups (table 2).

For the non-operated extremity, the following parameters had a statistically significant main time effect in each group: knee flexion ($p < 0.001$, $F [2, 0.548] = 13.593$), knee extension ($p = 0.001$, $F [2, 0.672] = 8.069$), hip flexion ($p = 0.046$, $F [2, 0.829] = 3.396$), hip abduction (p =

0.001, $F[2, 0.637]=9.393$), hip adduction ($p = 0.009$, $F[2, 0.749]=5.525$) ROMs, joint position sense 30° ($p < 0.001$, $F[2, 0.485]=17.531$) and joint position sense 60° ($p < 0.001$, $F[2, 0.438]=21.136$). No statistically significant group-by-time interaction was observed for these outcomes between groups. In addition, no statistically significant main time effect or group-by-time interaction was observed for hip internal and external rotation ROMs (table 3). Additionally, all patients in each group demonstrated improved hip external rotation at the second postoperative week at the beginning of rehabilitation ($p = 0.043$).

The statistical analysis of the ROM and joint position sense for the operated limb are presented in table 4. Similar to the non-operated limb, a statistically significant main time effect was observed within each group for the following parameters: knee flexion ($p < 0.001$, $F[2, 0.318]=35.370$), knee extension ($p< 0.001$, $F[2, 0.358]=29.639$), hip flexion ($p < 0.001$, $F[2, 0.516]=15.478$), hip abduction ($p = 0.029$, $F[2, 0.808]=3.932$), hip adduction ($p < 0.001$, $F[2, 0.592]=11.353$) ROMs, joint position sense 30° ($p < 0.001$, $F[2, 0.345]=31.314$) and joint position sense 60° ($p < 0.001$, $F[2, 0.499]=16.544$). However, no statistically significant group-by-time interaction was noted for these outcomes between groups. Additionally, no statistically significant intergroup main time effect was noted for hip internal rotation ($p = 0.099$, $F[2, 0.869]=2.488$) and external rotation ($p = 0.129$, $F[2, 0.883]=2.179$) ROMs. Furthermore, no statistically significant group-by-time interaction for hip internal and external rotation ROMs was found between groups.

Functional performance, KOOS score, and balance during each rehabilitation session were assessed, and the results are shown in table 5. During therapy sessions, a statistically significant main time effect was noted for TUG ($p < 0.001$, $F[2, 0.427]=22.107$, 5-SST ($p < 0.001$, $F[2, 0.279]=42.677$), BBS ($p < 0.001$, $F[2, 0.088]=171.114$), KOOS-Pain ($p < 0.001$, $F[2, 0.073]=210.315$), KOOS-Symptoms ($p < 0.001$, $F[2, 0.121]=119.806$), KOOS-ADL ($p < 0.001$, $F[2, 0.059]=265.083$), and except KOOS-QoL ($p < 0.001$, $F[2, 0.074]=206.102$), but not KOOS-SRF. No statistically significant group-by-time interaction was observed for these intergroup outcomes between baseline and the second postoperative month. A significant interaction effect was only revealed between groups for the KOOS Sport and Recreation Function scores ($p = 0.185$, $F[2, 0.760]=5.222$). The KOOS-SRF score demonstrated significantly greater improvement in the sensorimotor group than in the core stabilization group ($p = 0.04$).

The results show that all patients showed a significant decrease in knee flexion ($p = 0.006$) and significant improvement in 300 joint position sense ($p = 0.013$), 5-STS ($p = 0.029$), as well as in all KOOS subscales ($p < 0.001$) in the second postoperative week, i.e. just before the beginning of the treatment. There were no unintended effects of the two programs.

Tab. 3. Comparison of non-operated extremities between groups

Assessment	Group	E0	E1	p^a	p^b	E2	p^c	ηp^2	p^d	ηp^2
Knee Flexion Degree	CS	111.26 ± 13.41	117.84 ± 10.72	0.067	0.600	123.21 ± 7.98	< 0.001	0.452	0.872	0.008
	SM	105.00 ± 19.04	108.71 ± 15.40			115.00 ± 12.28				
p^e		0.258	0.045			0.022				
Knee Extension Degree	CS	-6.47 ± 5.52	-4.84 ± 5.43	0.105	0.932	-1.42 ± 2.81	0.001	0.328	0.294	0.072
	SM	-5.47 ± 5.26	-4.00 ± 5.06			-2.94 ± 3.94				
p^e		0.582	0.635			0.189				
Hip Flexion Degree	CS	98.26 ± 9.86	103.00 ± 9.09	0.190	0.341	103.58 ± 7.49	0.046	0.171	0.382	0.057
	SM	97.18 ± 14.14	97.94 ± 7.91			102.00 ± 5.36				
p^e		0.789	0.086			0.477				

Assessment	Group	E0	E1	p^a	p^b	E2	p^c	ηp^2	p^d	ηp^2
Hip Abduction Degree	CS	33.00 ± 5.54	31.89 ± 3.33	0.961	0.337	35.32 ± 5.15	0.001	0.363	0.542	0.036
	SM	32.29 ± 7.75	33.29 ± 6.72			35.76 ± 5.25				
p^e		0.753	0.427			0.797				
Hip Adduction Degree	CS	23.21 ± 6.77	25.58 ± 4.84	0.069	0.896	26.89 ± 4.88	0.009	0.251	0.953	0.003
	SM	24.00 ± 4.51	26.06 ± 3.94			27.06 ± 3.45				
p^e		0.687	0.748			0.909				
Hip Internal Rotation	CS	31.47 ± 9.19	32.00 ± 7.57	0.782	0.513	34.53 ± 4.64	0.367	0.059	0.374	0.058
	SM	32.47 ± 6.87	31.18 ± 8.86			32.06 ± 6.20				
p^e		0.717	0.766			0.183				
Hip External Rotation	CS	30.68 ± 9.63	34.58 ± 6.50	0.043	0.802	34.89 ± 5.24	0.081	0.141	0.779	0.015
	SM	31.82 ± 8.14	34.88 ± 10.22			33.94 ± 4.38				
p^e		0.706	0.915			0.561				
Joint Position Sense 30°	CS	7.22 ± 3.63	6.62 ± 2.93	0.341	0.927	4.37 ± 1.78	< 0.001	0.515	0.356	0.061
	SM	8.80 ± 4.91	8.08 ± 3.73			4.22 ± 2.79				
p^e		0.276	0.199			0.853				
Joint Position Sense 60°	CS	6.08 ± 3.36	8.00 ± 3.68	0.360	0.262	4.00 ± 2.20	< 0.001	0.562	0.507	0.040
	SM	6.63 ± 5.61	6.44 ± 2.44			3.52 ± 1.99				
p^e		0.721	0.148			0.504				

CS- Core Stabilization group, E0- preoperative evaluation, E1- pretreatment evaluation at second week post-op, E2- post-treatment evaluation at eight weeks post-op, SM Sensorimotor group

[a]2-by-2, mixed-model repeated measures ANOVA (main time effect),

[b]2-by-2, mixed-model repeated measures analysis (group-by-time interaction),

[c]2-by-3, mixed-model repeated measures ANOVA (main time effect),

[d]2-by-3, mixed-model repeated measures ANOVA (group-by-time interaction),

[e]independent samples t-test,

ηp^2- partial eta squared

Tab. 4. Comparison of operated extremities between groups

Assessment	Group	E0	E1	p^a	p^b	E2	p^c	ηp^2	p^d	ηp^2
Knee Flexion Degree	CS	99.89 ± 16.22	88.42 ± 1616	0.006	0.579	104.84 ± 8.93	< 0.001	0.682	0.832	0.011
	SM	96.94 ± 23.23	89.12 ± 13.39			105.29 ± 10.51				
p^e		0.658	0.890			0.890				
Knee Extension Degree	CS	-7.53 ± 5.60	-8.63 ± 6.05	0.692	0.495	-3.42 ± 3.87	< 0.001	0.642	0.703	0.021
	SM	-8.00 ± 5.20	-7.71 ± 4.08			-3.65 ± 3.67				
p^e		0.795	0.599			0.859				
Hip Flexion Degree	CS	94.26 ± 12.15	97.63 ± 11.10	0.093	0.827	103.05 ± 7.26	< 0.001	0.484	0.961	0.002
	SM	94.35 ± 15.21	98.71 ± 8.75			104.29 ± 7.01				
p^e		0.984	0.751			0.606				
Hip Abduction Degree	CS	32.68 ± 5.89	33.11 ± 6.06	0.426	0.704	36.84 ± 6.39	0.029	0.192	0.642	0.026
	SM	32.35 ± 8.15	33.53 ± 8.8.62			34.82 ± 5.54				
p^e		0.889	0.864			0.322				
Hip Adduction Degree	CS	21.68 ± 6.49	24.42 ± 6.23	0.139	0.591	26.63 ± 3.78	< 0.001	0.408	0.849	0.010
	SM	23.06 ± 6.33	24.35 ± 4.25			27.00 ± 4.95				
p^e		0.526	0.970			0.802				

Assessment	Group	E0	E1	p[a]	p[b]	E2	p[c]	ηp²	p[d]	ηp²
Hip Internal Rotation	CS	30.89 ± 7.73	33.37 ± 8.38	0.151	0.770	34.74 ± 5.03	0.099	0.131	0.821	0.012
	SM	31.71 ± 7.83	33.35 ± 8.20			33.88				
p[e]		0.757	0.996			0.683				
Hip External Rotation	CS	33.26 ± 9.29	31.68 ± 5.45	0.635	0.553	35.05 ± 6.34	0.129	0.117	0.751	0.017
	SM	30.76 ± 8.30	30.94 ± 6.82			32.53 ± 4.31				
p[e]		0.403	0.719			0.177				
Joint Position Sense 30°	CS	8.52 ± 3.36	7.96 ± 3.04	0.013	0.064	4.42 ± 2.42	< 0.001	0.655	0.185	0.097
	SM	11.60 ± 4.43	8.11 ± 3.06			5.35 ± 2.95				
p[e]		0.024	0.889			0.306				
Joint Position Sense 60°	CS	7.40 ± 3.17	7.14 ± 2.95	0.879	0.897	3.74 ± 1.54	< 0.001	0.501	0.759	0.017
	SM	6.95 ± 6.11	6.93 ± 2.53			4.24 ± 2.31				
p[e]		0.779	0.817			0.448				

CS- Core Stabilization group, E0- preoperative evaluation, E1- pretreatment evaluation at second week post-op, E2- posttreatment evaluation at eighth week post-op, SM-Sensorimotor group,

[a]2-by-2, mixed-model repeated measures ANOVA (main time effect),

[b]2-by-2, mixed-model repeated measures analysis (group-by-time interaction),

[c]2-by-3, mixed-model repeated measures ANOVA (main time effect),

[d]2-by-3, mixed-model repeated measures ANOVA (group-by-time interaction),

[e]independent samples t-test,

ηp^2- partial eta squared

Tab. 5. Comparison of assessments between groups

Assessment	Group	E0	E1	p^a	p^b	E2	p^c	ηp^2	p^d	ηp^2
TUG	CS	22.23 ± 8.43	22.17 ± 6.36	0.072	0.065	17.27 ± 4.90	< 0.001	0.573	0.187	0.097
	SM	20.47 ± 5.73	25.03 ± 9.04			17.02 ± 3.50				
p^e		0.475	0.276			0.864				
5-SST	CS	19.77 ± 4.80	22.02 ± 5.86	0.029	0.997	17.71 ± 4.15	< 0.001	0.721	0.055	0.161
	SM	21.55 ± 4.13	23.78 ± 6.27			17.26 ± 4.04				
p^e		0.247	0.389			0.743				
BBS	**CS**	39.94 ± 9.54	36.84 ± 4.92	0.798	0.070	51.58 ± 3.46	< 0.001	0.912	0.193	0.095
	SM	37.52 ± 6.96	39.88 ± 7.26			52.12 ± 2.52				
p^e		0.396	0.147			0.601				
KOOS-Pain	**CS**	31.53 ± 18.08	54.68 ± 11.06	< 0.001	0.337	77.37 ± 10.42	< 0.001	0.927	0.474	0.044
	SM	33.24 ± 15.20	61.82 ± 11.76			80.82 ± 9.75				
p^e		0.782	0.069			0.313				
KOOS-Symptoms	**CS**	53.42 ± 15.66	68.47 ± 13.28	< 0.001	0.176	83.89 ± 9.52	< 0.001	0.879	0.400	0.054
	SM	47.53 ± 22.11	71.53 ± 11.80			85.41 ± 8.86				
p^e		0.359	0.473			0.625				
KOOS-ADL	**CS**	36.37 ± 20.09	59.26 ± 14.04	< 0.001	0.637	81.95 ± 10.80	< 0.001	0.941	0.781	0.015
	SM	37.71 ± 13.17	63.24 ± 12.68			83.35 ± 7.47				
p^e		0.817	0.382			0.657				
KOOS-SRF	**CS**	1.05 ± 3.56	13.95 ± 10.87	< 0.001	0.311	28.95 ± 8.26	< 0.001	0.918	0.011	0.240
	SM	0.29 ± 1.21	17.94 ± 16.30			39.41 ± 12.10				
p^e		0.410	0.389			0.004				

Assessment	Group	E0	E1	p^a	p^b	E2	p^c	ηp^2	p^d	ηp^2
KOOS-KrQol	CS	19.16 ± 11.47	35.11 ± 12.23	< 0.001	0.505	59.74 ± 10.32	< 0.001	0.926	0.777	0.015
	SM	19.12 ± 12.94	39.06 ± 13.28			62.35 ± 9.034				
p^e		0.992	0.359			0.427				

ADL- Activities of Daily Living, BBS- Berg Balance Scale, CS- Core Stabilization group, E0- preoperative evaluation, E1- pretreatment evaluation at second week post-op, E2- posttreatment evaluation at eighth week postop, KOOS- Knee Injury and Osteoarthritis Outcome Score, KrQol- Knee-related quality of life, SM- Sensorimotor group, SRF- Sport and Recreation Function, SST- Sit to Stand Test, TUG- Timed Up and Go Test,

a 2-by-2, mixed-model repeated measures ANOVA (main time effect),

b2-by-2, mixed-model repeated measures analysis (group-by-time interaction),

c2-by-3, mixed-model repeated measures ANOVA (main time effect),

d2-by-3, mixed-model repeated measures ANOVA (group-by-time interaction),

eindependent samples t-test,

ηp2- partial eta squared

Discussion

Our findings indicate that both rehabilitation programs ensured significant improvement in range of motion and proprioception for both limbs, functional performance, and balance during rehabilitation after TKA. Significantly, neither program was not necessarily more effective for all other outcomes: the two interventions appear to have similar effects, except regarding sports and creative functions. However, the SM group demonstrated significantly better recovery in KOOS sports-recreative function compared to CS. Furthermore, while only knee flexion angle and proprioception improved after surgery, all parameters had significantly improved by the end of the programmes. This improvement was also observed in the nonsurgical extremity. Additionally, this trial demonstrated that core stabilization exercises are effective for reducing the fall risk and pain, and for improving function after TKA.

Although different exercise interventions have been applied for treatment, a standard rehabilitation approach has not yet been determined [17,42]. It has been suggested that rehabilitation should be started as early as possible to ensure restoration of function and proprioception [22,29]. Barker et al. [18] report no important difference between home-based rehabilitation, outpatient rehabilitation, or supervised rehabilitation after TKA. Even so, it seems that using postoperative home-based exercise programs at an early stage is practical and useful.

Range of motion (ROM) is the most widely-used outcome in evaluating rehabilitation [42,43]. A dissatisfaction rate of 20 to 30% because of the range of motion has been reported by patients after one year of TKA [42-44]. Our present results reveal significant differences between pre- and post-treatment for both training programs, and that improvement in ROM was observed for both the non-operated and operated extremities. As previous studies reported that active ROM exercises help pain relief and increase functional capacity at early postoperative stages [19,45], the active muscle contraction in the SM and CS programs may have a positive impact on increasing function and reducing pain. Bade et al. [8] reported knee plateau extension angle at six months postoperatively, whereas knee flexion plateaued at three months with 1120. As this study was terminated in the postoperative second month, the plateau variables were not evaluated; however, the final angles were close to these references. It is thought to be an acute effect because the measurement was performed immediately after the six-week program.

A recent meta-analysis showed that proprioceptive training is more effective than nonproprioceptive training in improving pain, stiffness, function, muscle strength, and JPS in patients with OA [46]. In addition, sensorimotor home-based exercises have been proven to restore neuromuscular activation and muscle strength [46,47].

A trial on patients with OA found sensorimotor training to yield significant improvements on joint position sense compared to traditional training [48]. Another study comparing sensorimotor and functional training after TKA found greater improvements in JPS in the sensorimotor group at bilateral extremities [22]. Therefore, these authors recommend SMT incorporating rehabilitation as being clinically effective [7,22,46].

Similar to the sensorimotor results, recent studies have found core stabilization exercises contribute to improvement in proprioception and postural control [28,29,40]. The mechanism of action has been attributed to the eccentric exercises stretching the muscle spindle and increasing its sensitivity. Such activity may provide better sensory nerve conduction from the muscle spindles to the central nervous system, resulting in a greater awareness of joint position sense and kinesthesia [32]. Previous studies have demonstrated that CS training leads to a recovery in balance and function, as well as a reduction in pain, symptoms, and falling risk [25,29,40].

Our present findings indicate no differences in any parameters between the two training regimens, except for KOOS-recreation and sport. However, it is promising that both study groups showed significant improvements in position sense at 30º and 60º knee flexion in both bilateral lower limbs during the rehabilitation period. This may have been due to both programs including content involving both lower extremities. In addition, while some studies have shown improvement in proprioception due to restoration of joint alignment, others do not indicate any improvement in proprioception following surgery [49]. Although this finding is still controversial, in the present study, the position sense of the operated limb improved significantly at 30º knee flexion in both groups between assessments E0 and E1. This may be associated with the observed reduction in edema, inflammation, pain, and symptoms in the postoperative period. Furthermore, it is possible that supplementing standard rehabilitation during hospital care with active ROM exercises may have stimulated more proprioceptive receptors in the early phase; this is consistent with previous studies [19].

Researchers reported that 25% of patients receiving TKA had balance problems and a history of falls one year after the operation [8,50]. Therefore, it has been proposed that balance training should be included in the acute stage rehabilitation program to reduce fall risk [7,12,51]. The BBS and TUG Tests are significant fall indicators, with a BBS score of 38 points or less indicating a 90% fall risk [52], and TUG score of more than 14 seconds a 63% to 89% risk [13]. In the present study, both programs were found to reduce of the risk of falling in all participants: all were at higher risk of falling before the treatment but not at risk of falling at the end of treatment. A significant negative correlation ($p < 0.01$) was found between BBS and TUG scores, implying that as balance control improves, functional performance also increases.

Although both groups demonstrated significant improvements after treatment worth regard to functional performance, no such difference was observed between the groups. However, all individuals obtained longer time for 5-SST at post-op week two compared to the baseline; the performance was significantly increased in both groups with the treatment. Previous trials have reported similar findings [12,13,19]. While the effects of core stabilization on functional performance are still unclear, the CS group exhibited significant improvement in both balance and functional tests. Some studies have found CS to achieve improved functional performance [23], but not others [29,53,54]. Additionally, Joshi et al. [55] found a positive correlation between core endurance and balance.

Both groups showed significant improvements based on all KOOS subscales; however, no significant differences between the groups were observed, except for the KOOS sports-recreational subscale: sports and recreational activities were found to improve more in the SM group. The role of asymmetries in lower extremity muscle strength and functional performance for future injuries remains unclear [56,57]. However, a significant relationship between injury duration and a difference in bilateral jumping function has been noted in basketball players [57]. In the present study population, it is possible that the sports and recreational functions of the patients were relatively poor due to the long-term degeneration associated with OA, reflected in the low KOOS sportive recreational activities subscale values, and the balance and proprioception exercises performed during the programme contributed to bilateral healing during the restoration process.

Connelly et al. [58] define patient acceptable symptom status (PASS) as a state in which the current symptom status of a patient is judged as acceptable. The KOOS results of both of our groups at the end of treatment were close to previously determined PASS threshold values [59]. This finding is an indicator of the benefit of both exercise programs.

Limitations

The lack of a control group and long-term follow-up and the relatively small sample size are considered to be important limitations. In addition, as the effects of the programmes on quality of life and function remain unclear, a long-term follow-up is recommended in future studies. Future research should also include a control group to compare and muscle strength evaluations.

Clinical implication

- Both training programs are effective for treating the operated extremity; however, one program was not superior to the other for all clinical outcomes.

- Core stabilization exercises are safe and beneficial methods for improving balance, proprioception, function, range of motion and functional performance in TKA rehabilitation programs starting from the subacute period.
- Sensorimotor exercises more effective for improving sportive and recreational functions.
- Both programs contribute to the functional recovery of the bilateral extremity.
- Improvement in joint position sense at small angles was observed in the early period following surgery.

Conclusions

Core stabilization home-based exercises resulted in improvement of proprioception, balance, function, and ROM after TKA. Although the sensorimotor and core stabilization programs were both effective on bilateral limbs, sensorimotor training was more effective than CS at sportive-recreational functions. It was also found that surgery provided spontaneous improvement in both proprioception and knee flexions in the early period without rehabilitation.

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Conflicts of interest

The authors declare no conflict of interest.

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