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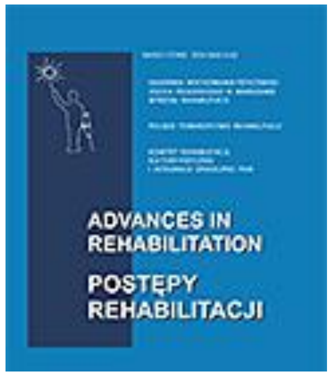

Authors: Ebru Gülek Karadüz, Riza Emrah Demirbaş, Ayça Yağcioğlu, Şule Badilli Hantal

Ebru Gülek Karadüz - 0000-0001-6658-0042
Riza Emrah Demirbaş - 0009-0000-0739-1794
Ayça Yağcioğlu - 0000-0002-8942-1893
Şule Badilli Hantal - 0000-0002-9018-8777

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Sensorimotor versus Core Stabilization Home Exercise Programs Following Total Knee Arthroplasty: A Randomized Controlled Trial

Ebru Gülek Karadüz*[1,2,A-F], Riza Emrah Demirbaş[3,A-B,F], Ayça Yağcioğlu[4,B-C,E-F], Şule Badilli Hantal[4,A,C,E-F]

[1]Istanbul Medipol University, Department of Physiotherapy and Rehabilitation, Graduated School of Health Science, Istanbul, Turkey
[2]Vocational School of Health Services, Osmangazi University, Eskişehir, Turkey
[3]Tuzla Gispir Hospital, Orthopeadics and Traumatology, Istanbul, Turkey
[4]Yeditepe University, Health Science Faculty, Physical Therapy and Rehabilitation Department, Istanbul, Turkey

Abstract

Introduction: Although total knee arthroplasty (TKA) is a frequently performed surgery, a standard rehabilitation approach has not yet been established. The study aimed to investigate 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) undergone unilateral TKA. Participants were randomly allocated to either the sensorimotor group (N = 20) or core stabilization group (N = 20). Patients performed exercise programs over 6 week between second and eighth weeks postoperatively. Proprioception, knee and hip range of motion, Knee Injury and Osteoarthritis Outcome Scale, 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: A statistically significant improvement was found in both groups for all outcomes between E1 and E2 ($p < 0.05$). However, the difference between the groups was found only in the KOOS-sportive recreational activities ($p < 0.001$), favoring the sensorimotor group. Additionally, the 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 contribute to improvement in rehabilitation through non-operated extremity.

Keywords: Functional Performance, Knee, Rehabilitation, Replacement, Arthroplasty

***Correspondence:** Ebru Gülek Karadüz; Istanbul Medipol University, Department of Physiotherapy and Rehabilitation, Graduated School of Health Science, Istanbul, Turkey; email: ebrugulek.karaduz@ogu.edu.tr

Introduction

Osteoarthritis (OA) is a chronic, progressive, and degenerative disease leading to pain and function limitation 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 surgery to relieve symptoms and realign joint mechanics [5-7]. While TKA is commonly performed, postoperative deficits potentially constrain functional performance [8]. Previous studies reported dissatisfaction rates as 30% of patients five years after surgery [9], and 28.9% of patients had still pain and undesired functional levels following two years [4]. Therefore, rehabilitation plays a crucial role in the management of potential problems after TKA.

In the aging process, 30-40% of muscle strength and proprioception decrease in the lower extremities. Thus, patients experience instability problems in addition to joint degeneration before surgery [10,11]. Restored structures with surgery are affected in terms of sensorimotor function through mechanoreceptors, muscle strength, postural instability, and proprioception loss. As a result, the risk of falls and the tendency to lose postural control increase after TKA [7,12,13]. The 45% rate of falling is reported which is still very high because of the partial restoration of the sensorimotor system following rehabilitation [14]. Some studies reported 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 climbing of stairs compared to the healthy group after TKA [17]. Therefore, TKA remains the most common reason for falling and functional limitation [18].

In current clinical practice, diverse complementary therapies are incorporated into TKA rehabilitation; however, exercise is one of the most frequently preferred and evidence-based methods [19,20]. While it is known that rehabilitation is effective compared to non-intervention, it remains unclear which exercise is more effective [21]. Among the therapies, sensorimotor training (SMT), and *neuromuscular training*, is a combination of proprioceptive and balance exercises approach. SMT aims at the facilitation of proprioceptors to improve strength 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 early 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 exercise prescription [16]. Core stabilization (CS) is another exercise approach that 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 may be one of the treatment options to protect against falls and functional performance [27,28]. Although the concept has been frequently used in rehabilitation, especially for low back pain, a few trials demonstrated the clinical effects after TKA [28,29].

To our current knowledge, limited research exists in the literature regarding the effectiveness of CS on different outcomes after TKA. This study's findings are significant as they illustrate the effects of CS on various parameters and compare them with SM after TKA. In addition, these previous trials did not investigate the effects on bilateral lower extremities in different outcomes. For instance, this study focused on the non-operated limb of different exercise program's efficiency. Therefore, the 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 hypothesized that all outcomes would improve in two groups, but one method had more advantages 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 Orthopedics 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 enrollment. The study protocol was registered at ClinicalTrials.gov (ID: NCT05248854).

Participants were invited to the study and explained the purpose, methodology, and risks of trialing a therapist after the doctor firstly examined and planned to surgery date. Patients confirmed and signed the information form and the baseline assessments were performed before surgery. Participants have taken the same hospitalization care during the postoperative two weeks and met again with patients. All measurements were performed at baseline (E0) before surgery, postoperative second weeks control at the beginning of treatment (E1) and following 6 weeks treatment (E2) by the same therapist.

Participants

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

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

Surgery was performed by the same physician, followed by three assessment periods by a therapist who did not know the treatment groups, and interventions were given by an another therapist. The physician and therapist who assessed 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 sample size of the study, and numbers from 1 to 46 were randomly assigned to two groups on the website. Each number was included in one of two groups, and as patients sought treatment sequentially. The therapist providing the intervention directed the patients to the group appropriate to their order.

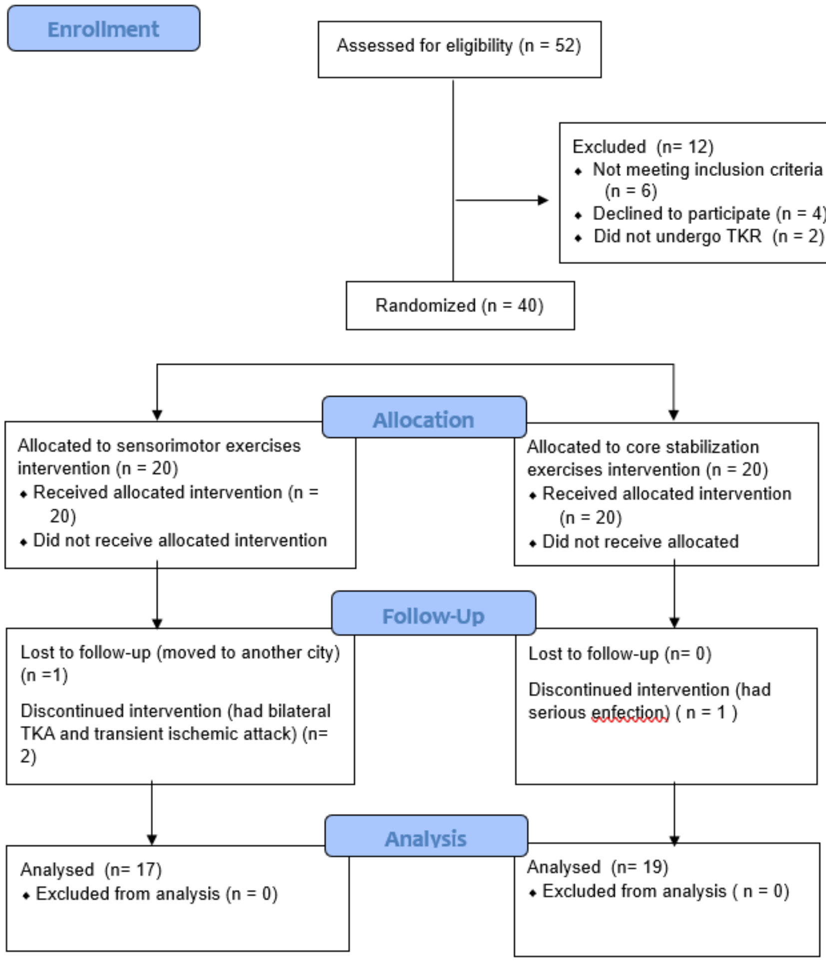

Fig. 1. CONSORT flow chart of the study

Sample size

The sample size was calculated with the "PS Power sample size calculator" program. When the calculations are taken as a 2.8 standard deviation value and minimal clinically significant change of 3 points of Berg Balance Scale in the 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 thirty-eight patients are enough, 20% more were included in case the possibility of dropping out, total forty-six participants were incorporated into the study.

Outcome measures

The primary outcome measure was balance which is evaluated with the Berg Balance Scale (BBS); and secondary outcomes were knee joint position sense (JPS), range of motion (ROM) 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 asses the static balance and fall risk. The scale contains different tasks scored between 0-4 points, with a total score between 0-56. A higher score means a better balance level [30]. Reliability and validity of Turkish version have been performed [31].

The ROM of the hip and knee joints was evaluated with a universal goniometer. *JPS* was assessed for 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]. The therapist showed target reference 30^0 and 60^0 active knee flexion angles passively three times (starting from a completely extended position), kept it for 10 seconds, and returned to the initial position during sitting. After that, the client actively performed the target angles with eyes closed and three deviated angles were recorded.

The *Sit-To-Stand-Up Test* and *Timed–Up and Go Test* were applied to evaluate functional performance, balance, and fall risk. Validity and reliability of the tests have been carried out [36,37]. The patients practice sitting and standing up 5 times as fast as possible during the STS test, time records the elapsed time [36]. In the TUG test, patients stand up independently from the chair, walk 3 m, turn around the predetermined point, and sit again at the starting point; the time was recorded [37]. The minimum 2.49 seconds difference exhibits fine clinical meaning change and below 14 seconds during performance shows a higher risk of falling [20]. The Turkish version validity and reliability of performance tests were also available [38].

The *KOOS* was used to evaluate physical evaluation. The scale contains 42 Likert questions and 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 means lacking knee problems. The reliability and validity of Turkish version was performed [39].

Intervention

In this two-armed trial, one group was given CS and the other performed the SM exercises. Exercise programs were explained and performed on patients by the therapist and hand brochures were given to home at the beginning of the treatment. Treatment programs were sustained between postoperative second and eighth weeks. All participants were desired to perform four sessions per week, taking 20 minutes, over six weeks as a home-based program. Patients were controlled via telephone per week and checked during face-to-face interviews in the postoperative fourth weeks during treatment.

The SM program contained a combination of traditional strengthening and stretching exercises, various balance and proprioceptive exercises consisting of side-stepping, tandem walking, perturbation exercise 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 contained traditional hip and knee strengthening and stretching exercises combining core stabilization as 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]. Progression of programs was provided at face-to-face interviews during the fourth week of control. All of the organizing the methodological description of this trial showed with SPIRIT table at Figure 2.

Statistical analysis

Statistical analysis were performed using the "Statistical Package for Social Sciences" (SPSS) version 21.0. Visual (histogram, probability graphs), skewness and kurtosis value, and analytical methods (Kolmogorov-Smirnov / Shapiro-Wilk's test) were used to define whether the variables were normally distributed. Parametric tests were used in the analyses since all data conformed to a normal distribution. In the analysis of the data, categorical variables were expressed as a percentage (%) and the number of people (n), while mean and standard deviation (sd) values were defined for continuous variables. In the comparison of the demographic data and between groups study groups, an independent samples t-test was used for numerical variables, while chi-square analysis was used for categorical data. "2-by-2 Mixed Model Repeated Measures ANOVA" and "2-by-3 Mixed Model Repeated Measures ANOVA" tests were used to compare the evaluation parameters as group and time. The partial eta squared (ηp^2) value was taken into account in determining the effect size between the variables. The partial eta squared value is classified as small (0.01), medium (0.06), and large (0.14) [41].

	Enrolment	Allocation		
TIMEPOINT**		E0	E1	E2
ENROLLMENT				
Physician examination	X			
Eligibility screen	X			
Informed consent	X			
Allocation		X		
INTERVENTIONS				

Sensorimotor exercises group			←	→
Core stabilization exercises group			←	→
ASSESMENTS				
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 specific timepoints in this row. E0- preoperative evaluation, E1- pretreatment evaluation at postop second weeks, E2- posttreatment evaluation at postop eighth weeks

Fig. 2. Content for the schedule of study

Results

Fifty-two patients scheduled for TKA were assessed for eligibility. Patients (N = 46) who satisfied the inclusion criteria and finally forty participants (N = 40) were randomly assigned to the core stabilization or sensorimotor groups. Because of the dropout of patients, thirty-six patients (69,38 ± 5,81 years) completed the treatment (Figure 1). Baseline data were similar in both groups (Table 1).

Tab. 1. 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

According to the non-operated extremity results, there was a statistically significant main time effect for 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° ($p < 0.001$, $F [2, 0.438] = 21.136$) in both groups, while there was no statistically significant group-by-time interaction for these outcomes between groups. In addition, there was not found statistically significant main-time effect and group-by-time interaction for hip internal and external rotation ROMs (Table 2). Additionally, all patients in either group had improved hip external rotation at the second postoperative week at the beginning of the rehabilitation ($p = 0.043$).

Tab. 2. Comparison of non-operated extremities between groups

Assessment	Group	E0	E1	p[a]	p[b]	E2	p[c]	ηp²	p[d]	ηp²
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				
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 postop second weeks, E2 posttreatment evaluation at postop eighth weeks, 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

The statistical results of the operated limb ROM and joint position sense are presented in Table 3. Similar to the non-operated limb, there was a statistically significant main time effect for 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) in both intergroup, while there was no statistically significant group-by-time interaction for these outcomes between groups. Additionally, there was no statistically significant main time effect 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 intergroup. Additionally, no statistically significant group-by-time interaction for hip internal and external rotation ROMs was found between groups.

Functional performance, KOOS, and balance during each rehabilitation session were assessed, and the results are shown in Table 4. During therapy sessions, there was a statistically significant main time effect 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. There was also no statistically significant group-by-time interaction on these intergroup outcomes between the 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). KOOS-SRF improvement in the sensorimotor group was significantly better than that in the core stabilization group ($p = 0.04$).

The results show that all patients showed a statistically significant decrease in knee flexion ($p = .006$) and significant improvement in 30^0 joint position sense ($p = 0.013$), 5-STS ($p = 0.029$), and all KOOS subscales ($p < 0.001$) in the second postoperative weeks, just before on the begining of the treatment. There were no unintended effects of the two programs.

Tab. 3. Comparison of operated extremities between groups

Assessment	Group	E0	E1	p[a]	p[b]	E2	p[c]	ηp2	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				
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 postop second weeks, E2- posttreatment evaluation at postop eighth weeks, 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),

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[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 assessments between groups

Assessment	Group	E0	E1	p^a	p^b	E2	p^c	ηp2	p^d	ηp2
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				
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 postop second weeks, E2- posttreatment evaluation at postop eighth weeks, 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),

[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

Discussion

This study's results showed that both rehabilitation programs ensured significant improvement in range of motion and proprioception bilaterally, functional performance, and balance in the TKA rehabilitation. Another important point to consider was that one of the programs was not necessarily more effective in all other outcomes. The findings suggest that the two interventions have similar effects except for sports and creative functions. We found significant recovery in KOOS sports-recreative function in the SM group compared to CS. Furthermore, while only knee flexion angle and proprioception improved after surgery, all parameters significantly improved with rehabilitation programs at the end of the treatment. This improvement was also found in the nonsurgical extremity. Additionally, this trial demonstrated that core stabilization exercises are effective in reducing the fall risk, and pain and improving function after TKA.

Although different exercise interventions have been applied in the treatment, a standard rehabilitation approach has not yet been determined [17,42]. Rehabilitation was suggested to start at the earliest process for function and proprioception restoration [22,29]. Barker et al. [18] reported that there was no important difference between home-based rehabilitation, outpatient rehabilitation, or supervised rehabilitation after TKA. For instance, it seems that using postoperative home-based exercise programs at an early stage is practical and useful.

Range of motion is the most used outcome [42,43]. It is reported dissatisfaction rate of 20-30% of patients after one year of TKA [42-44]. Our study results exhibited significant differences between pre-post treatment at both training programs which means improvement was seen on the ROM of the non-operated extremity as well as the operated extremity. As previous studies reported that active ROM exercises help pain relief and increase functional capacity at early postoperative stages [19,45], SM and CS programs may have a positive impact on increasing function and reducing pain due to involving active movements. Bade et al. [8] reported knee plateau extension angle at six months postoperatively, whereas knee flexion plateaued at three months with 112^0. As this study was terminated in the postoperative second month, the plateau variables were not evaluated. However, end angles were close to these references. It is thought to be an acute effect because the measurement was performed immediately after the 6-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 compared sensorimotor versus traditional training in joint position sense in OA and researchers reported significant improvements in the sensorimotor group [48]. Another previous study compared sensorimotor and functional training after TKA, more improved JPS was seen in the sensorimotor group at bilateral extremities [22]. Therefore, the authors recommend SMT incorporating rehabilitation to be clinically effective [7,22,46]. Similar to sensorimotor results, current studies have reported the effects of core stabilization exercises on proprioception and postural control [28,29,40]. The mechanism of action is explained as increased sensitivity of the muscle spindle by stretching with eccentric exercises. It may provide better sensory nerve conduction from muscle spindles to the central nervous system, resulting in more awareness of joint position sense and kinesthesia [32]. Previous studies have demonstrated that CS training leads to the recovery in balance and function, reduction of pain, symptoms, and falling risk [25,29,40]. According to our findings, there was no difference in the intergroup in any parameters except KOOS-recreation and sport. However, it is a pleasuring that both study groups showed significant improvement in the position sense at 30º and 60º knee flexion in both bilateral lower limbs during the rehabilitation period. It is thought that the content of the programs involving both lower extremities led to these findings. In addition, some studies have shown improvement in proprioception due to restoration of joint alignment, but some studies have not supported a finding of improvement in proprioception thanks to surgery [49]. Although this finding is still controversial, we found that the 30º knee flexion position sense of the operated limb improved significantly in both groups between E_0 and E_1 assessments. The reduction in edema, inflammation, pain, and symptoms in the postoperative period is thought to reason for this finding. Furthermore, it is thought that standard rehabilitation during hospital care including active ROM exercises may have led to the stimulation of more proprioceptive receptors in the early phase, consistent with previous studies [19].

Researchers reported that 25% of patients had balance problems and a history of falls one year after TKA [8,50]. Therefore, balance training is suggested to reduce falls in the acute stage rehabilitation program [7,12,51]. BBS and TUG Tests are significant fall indicators 38 points or less of BBS indicates 90% fall risk [52], TUG test score of more than 14 seconds demonstrates having a 63% - 89% tendency to fall [13]. In this study, while all participants were at higher risk of falling before the treatment, all participants were below the risk at the end of the treatment. This result showed that both programs succeeded reduction of the risk of falling. Finding a significant negative correlation ($p < 0.01$) between BBS and TUG scores implies that as balance control improves, functional performance also increases.

Although our functional performance tests revealed a significant improvement in both groups after treatment, there was no difference between the groups. However, all individuals demonstrated a significantly prolonged duration at the 5-SST test at postoperative second weeks, the performance was significantly increased in both groups with the treatment. Previous trials have reported similar results supporting our results [12,13,19]. While core stabilization effects on functional performance are still discussed, we found significant improvement in both balance and functional tests on the CS group. Some studies reported an advance in functional performance with CS [23], but some researchers did not encourage this finding [29,53,54]. Additionally, Joshi et al. [55] found a positive correlation between core endurance and balance.

Results of all KOOS subscales showed significant improvement with treatment while there were no significant differences between the groups except the KOOS sports-recreational subscale. Sports and recreational activities were found more improved in the SM group. Previous studies have reported that the role of asymmetries in lower extremity muscle strength and performance for future injuries is still unclear and has provided limited evidence [56,57] A study conducted on athlete basketball players reported a significant relationship between injury duration and a difference in bilateral jumping function [57]. In this study population, it is thought that the osteoarthritis process seriously affects the sports and recreational functions of the patients due to the long-term degeneration process of disease and the KOOS sportive -recreational activities subscale values were found to be quite low. We thought that balance and proprioception exercises contribute to bilateral healing during the restoration process with content of the treatment programs. In addition, Connelly et al. [58] defined patient acceptable symptom status (PASS) which the patient's current symptom status was judged as acceptable. Threshold values according to PASS have been reported recently [59]. The KOOS results of both of our groups at the end of treatment were close to PASS values. This finding is an indicator of the benefit of both exercise programs.

Study limitations

The lack of a control group and long-term follow-up and the relatively small sample size are considered to be important limitations of our study. Long-term follow-up is recommended in future studies because of unknown effects on quality of life and function. A control group should be included to compare and muscle strength evaluations should be performed in future studies.

Clinical implication

- Two training programs are effective on operated extiremity while one of programs did not found more effective than other at all clinic outcomes.
- Core stabilization exercises are safe and beneficial to improve balance, proprioception, function, range of motion and functional performance in TKA rehabilitation programs starting from the subacute period.
- Sensorimotor exercises more effective to improve sportive and recreational functions.
- Both programs contribute to the functional recovery of the bilateral extremity.
- Improvement in joint position sense at small angles was found in the early period with surgery.

Conclusions

Core stabilization home-based exercises ensured improvement of proprioception, balance, function, and ROM after TKA. Although sensorimotor and core stabilization programs were effective on both bilateral limbs, one exercise approach was not found to be more effective than the other except for sportive-recreational functions. Sensorimotor training was more effective than CS at sportive-recreational functions. This study also exhibited that surgery provided spontaneous improvement in proprioception and a few knee flexions in the early period without rehabilitation.

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Conflicts of interest
The authors declare no conflicts of interest.

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