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Physical performance parameters during standing up in patients with unilateral and bilateral total knee arthroplasty

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Objective: The aim of this study was to compare quadriceps femoris muscle performance parameters of patients who underwent unilateral and bilateral total knee arthroplasty (TKA).

Methods: The study included 80 patients. Thirty-five underwent unilateral primary TKA (35 females; mean age: 67.11±3.97 years) and 45 underwent bilateral primary TKA (2 males, 43 females; mean age: 67.12±7.32 years). Patients were evaluated in terms of performance parameters including stand-up time, rising index, standing postural sway velocity, and symmetries of body weight distribution on the extremities while standing up using a Balance Master® balance and performance instrument in the postoperative 6th and 12th month.

Results: No significant difference was determined in body weight symmetry ratios between the operated and non-operated extremity in unilateral TKA patients in the 6th and 12th month sit-to-stand test ($p>0.05$) whereas there was a significant difference in bilateral TKA patients ($p<0.05$). There was no significant difference between unilateral and bilateral TKA patients in terms of time needed for standing up, rising index and gravity sway velocity at the postoperative 6th month and 12th month ($p>0.05$). Bilateral TKA patients stood up in a shorter time than unilateral TKA patients ($p<0.05$) although the degree of body sway was higher after standing up ($p<0.05$).

Conclusion: Bilateral TKA patients should be encouraged to focus on exercises with non-dominant limbs and to use them more while physiotherapy and rehabilitation programs including physical performance activities are planned.

Key words: Bilateral total knee arthroplasty; performance; sit-to-stand test; unilateral total knee arthroplasty.

Total knee arthroplasty (TKA) is one of the most common arthroplasty procedures and aims to reduce pain, ensure function and increase normal joint movements and independence level during activities of daily living.[1-3]

Performance-based physical and self-care criteria are used for the evaluation of the functional outcomes of patients.[4,5] Self-care criteria rely on the basis of a patient's evaluation of his/her functional activities through his/her own observations whereas physical

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performance tests are used to observe changes in the capability and functionality levels and for the evaluation of the patient during the performance of that functional activity.[4-6]

One of the main treatment goals is the regaining of functional activities. Therefore, evaluation parameters used to monitor patients are of importance for clinicians in planning and implementing physiotherapy and rehabilitation programs.[5,7,8]

The sit-to-stand test is an important test that focuses on the extensor mechanism of the knee and shows the contracting ability of the quadriceps femoris (QF) muscle strength.[9-12] During the sit-to-stand activity, it has been reported that QF muscle performance is correlated with the balance, postural sway, walking speed, and climbing and descending stairs. Patients can reach the normal values for these activities at the end of the 1st year following TKA.[9,10,12,13]

Although studies have been made comparing criteria, such as the duration of postoperative hospital stay, costs, complication rate, muscle strength, functional activity level, balance and functional scores of the knee joint in patients with unilateral and bilateral TKA,[7,14-16] there have not been many studies comparing the postoperative physical performance parameters.[12,17] Studies on this subject mostly focus on the comparison of patients with unilateral and bilateral TKA with healthy individuals or osteoarthritic patients.[3,13,18,19]

The present study aimed to determine the differences between the parameters regarding QF muscle performance during 6th and 12th month sit-to-stand tests in patients with unilateral and bilateral TKA.

Patients and methods

This study included 80 patients. Forty-five patients (2 males, 43 females) underwent bilateral TKA in a single operative session, and 35 female patients underwent unilateral TKA, depending on the patient's preferences, despite having two osteoarthritic knees. The right limb was dominant in all the patients undergoing bilateral TKA and 34 undergoing unilateral TKA. The non-operative knee was classified as Grade 3 and 4 according to the Kellgren-Lawrence classification in the patients undergoing unilateral TKA.

Patients were mobilized and asked to put weight on the operated limb as much as they could on the first postoperative day. All the patients followed a standard physiotherapy program in which they performed isometric and isotonic exercises, continuous passive motion, active-assisted active range of motion exercises, gait training, and transfer training under the supervision of a physiotherapist.[20-22]

Patients with knee infection, severe back pain, heart failure, severe foot deformities, and balance-sight problems due to neurological pathologies or those who underwent TKA revision or total hip arthroplasty following the surgery were excluded from the study.

Quadriceps femoris muscle performance of both groups was evaluated using a Balance Master® test device at the postoperative 6th and 12th month.[23,24] The parameters were as follows:

a. Weight transfer (in seconds): time elapsed until the moment of rising,
b. Rising index (percentage of the body weight): amount of force exerted on the platform during the rising phase,
c. Center of gravity (COG) sway velocity (in degrees per second): postural sway velocity during upright posture,
d. Left/right weight symmetry (percentage of body weight): symmetry of the body weight distribution on the lower extremities during the rising phase.

The test was repeated three times and the average values of the measurements were documented. Tests were taken with the knees in 90° of flexion and arms crossed over the chest. Balance Master® test blocks were used instead of chairs. All the patients completed the test successfully.

Patients who volunteered to participate in the study were informed about the assessment in detail and written informed consent forms were obtained.

The paired t-test and independent samples t-test were used for statistical analysis. P values of less than 0.05 were considered statistically significant.

Results

Patients with unilateral and bilateral TKA were similar in terms of their descriptive characteristics (Table 1).

No significant difference was detected between body weight symmetry rates on the operated and non-

Table 1. Descriptive characteristics of the patients. Values are expressed as mean±SD.

	Unilateral TKA (n=35)	Bilateral TKA (n=45)	p
Age (years)	67.11±3.97	67.12±7.32	0.937
Height (cm)	156.34±6.91	154.77±6.84	0.316
Body weight (kg)	75.71±8.50	79.15±12.95	0.178

TKA: Total knee arthroplasty

operated extremities of the patients undergoing unilateral TKA at the postoperative 6th and 12th month sit-to-stand tests (p>0.05) (Table 2).

When examining the ratio of body weight borne by the two extremities during the postoperative 6th and 12th month sit-to-stand tests of patients undergoing bilateral TKA, more weight was put on the dominant extremity (p<0.05) (Table 3).

There were no differences between the sit-to-stand test parameters of unilateral and bilateral TKA at the postoperative 6th month (p>0.05) (Table 4). However, patients who underwent bilateral TKA rose in a shorter time (p<0.05) but were only able to stand up with a higher degree of body sway than the unilateral TKA patients at the postoperative 12th month assessments (p<0.05) (Table 5).

Discussion

The ability to rise from a chair is one of the important functions that affect the level of independence in daily life. Thus, evaluation of this activity, easily affected by the orthopedic and neurological diseases, plays an important role in determining and treating functional deficits.[25] The Balance Master® performance device (NeuroCom® International, Inc., Clackamas, OR, USA) is one of the objective methods that can be used to measure patient performance and balance parameters. Good correlation has been reported between evaluation parameters of performance.[26] Therefore, in our study, we used this test device to evaluate patient's activity performance.

There are few studies comparing the physical performance of patients following unilateral and bilateral TKA in the literature.[7,12,17] Bakirhan et al. compared the early stage functional activities associated with physical performance in the hospital with the patients' physical performance and determined that unilateral TKA patients achieved functional activities such as sitting, rising and walking earlier.[7] Unver et al. determined that unilateral TKA patients became independent earlier than did bilateral TKA patients at the sit-to-stand test after the application of the same type prosthesis.[12] In a similar study, Mahoney et al.,[17] however, used different prostheses in their patients and determined that patients with bilateral TKA became independent earlier than unilateral TKA patients at the sit-to-stand test at the end of the 1st postoperative year, but also stated that this might be due to the fact that the types of prostheses they used were not homogeneous. Wang et al. investigated QF muscle activation in patients with single-axis and multi-axis TKA during sit-to-stand tests and determined that patients with single-axis TKA managed this activity with less muscle activation.[19] Unlike these studies, we investigated the differences between the physical performance parameters of the patients with unilateral and bilateral TKA during rising activity and determined that there was a significant asymmetric weight distribution between the dominant and non-dominant limbs, especially in patients with bilateral TKA.

Table 2. Comparison of the percentages of body weight symmetry between operated and non-operated extremities of patients with unilateral TKA during the sit-to stand test at postoperative 6th and 12th months.

	Operated extremity (mean±SD)	Non-operated extremity (mean±SD)	p
6th month	10.75±10.78	14.08±8.30	0.314
12th month	10.76±9.75	12.69±9.92	0.666

Table 3. Comparison of the percentages of body weight symmetry between right and left extremities of patients with bilateral TKA during the sit-to stand test at postoperative 6th and 12th months.

	Right extremity (mean±SD)	Left extremity (mean±SD)	p
6th month	7.52±9.90	1.30±3.18	0.000*
12th month	7.57±8.37	2.93±6.03	0.007*

*p<0.05

Table 4. Comparison of unilateral and bilateral TKA patients in terms of performance parameters during the sit-to stand test at postoperative 6th month.

	Unilateral TKA (mean±SD)	Bilateral TKA (mean±SD)	p
Weight transfer (s)	0.51±0.27	0.45±0.22	0.304
Rising index (% BW)	14.00±3.88	13.60±4.34	0.677
COG sway velocity (°/s)	3.68±1.41	4.06±1.00	0.160

TKA: Total knee arthroplasty, BW: Body weight, COG: Center of gravity

Table 5. Comparison of unilateral and bilateral TKA patients in terms of performance parameters during the sit-to stand test at postoperative 12th month.

	Unilateral TKA (mean±SD)	Bilateral TKA (mean±SD)	p
Weight transfer (s)	0.52±0.26	0.38±0.15	0.004*
Rising index (% BW)	13.97±4.67	14.77±4.95	0.461
COG sway velocity (°/s)	3.36±1.04	4.54±1.04	0.000*

*p<0.05, TKA: Total knee arthroplasty, BW: Body weight, COG: Center of gravity

During sit-to-stand test following TKA, the amount of body weight on both of the lower extremities is not equal or symmetric, which leads to the emergence of a number of prosthesis-related complications resulting from overload on the joint.[3] The number of studies examining the weight borne on the extremities during the sit-to-stand test is limited. Mizner and Snyder-Mackler[13] determined that patients with unilateral TKA transferred less weight to the operated extremity during the postoperative 3rd month sit-to-stand test. They concluded that this would accelerate the process of osteoarthritis in the already osteoarthritic, non-operated knee during the later stages due to overload. Boonstra et al. determined that weight asymmetries between the two extremities of patients with unilateral TKA compared to control group patients continued at the postoperative 6th- and 12th-month tests.[3] Our results differed from those of Boonstra et al.[3] and Mizner and Snyder-Mackler.[13] In our study, no difference was determined between the operated and non-operated limbs in terms of weight symmetry ratios of unilateral TKA patients at the postoperative 6th and 12th months (Table 2). These differences might be due to the fact that our patients regularly came to hospital follow-ups that included regular exercise programs and physical therapy programs of the osteoarthritic knee.

The bilateral TKA patients in our study significantly transferred their body weight to the dominant extremity at evaluations in the postoperative 6th and 12th months (Table 3). There is no study on weight transfers during rising to dominant and non-dominant extremities of patients with bilateral TKA in the literature. In a study of healthy individuals, it was determined that weight transfers between the dominant and non-dominant extremities were symmetric.[27] In our study, the impairment of postoperative weight symmetries in favor of the right extremity in bilateral TKA patients was likely due to the fact that the right limb was used more in functional activities of the daily life more as the dominant limb. However, in order to reach such a conclusion, patients should be evaluated before and after surgery for the comparison of preoperative and postoperative results. This was a limitation of our study. The reason why the dominant limb is more dominant during rising in bilateral TKA applications can be explained not by the peripheral control in the proprioceptive system but by the cortical level control. Since peripheral proprioceptors reach equal activity levels following bilateral TKA, they are monitored with the cortical level, which therefore is naturally shaped according to the dominant hemisphere. This favors the dominant extremity in patients with bilateral TKA and is a natural consequence of the proprioceptive system. This natural consequence was determined in this study as well. However, some complications in the structure of dominant limb prosthesis in patients with bilateral TKA may arise due to overload resulting from the development of weight asymmetry over time. Therefore, in order to achieve a symmetrical weight distribution between extremities during rising patients undergoing bilateral TKA should be provided exercises in which the non-dominant extremity is used.

Several studies reported a significant negative correlation between QF muscle strength and postural sway.[12,28] In our study, whereas there was no difference between patients undergoing unilateral and bilateral TKA at the postoperative 6th month in terms of time, rising index and postural sway parameters (Table 4), patients with unilateral TKA had better postural control while standing than bilateral TKA patients at the postoperative 12th month (Table 5). This result can be explained by the presence of mechanoreceptors in the osteoarthritic knees of unilateral TKA patients or by similar balance and proprioceptive sense interactions at different degrees of osteoarthritis.[29] It was determined that bilateral TKA patients were able stand up earlier than unilateral TKA patients (Table 5). In their evaluation of performance according to prosthesis type, Wang et al. found that patients with single-axis TKA were able to complete the sit-to-stand activity earlier than those undergoing multi-axis TKA.[30] In bilateral TKA applications, both knees undergo surgery and are used in functional activities without being protected, which contributes to the early recovery of reflex inhibition in the QF muscle and, as a result, these patients complete this activity earlier. In our study, bilateral TKA patients completed this activity in a shorter period of time, which can be explained by the increase in the activation of the QF muscle during the postoperative period and, though not clearly proved, by the pain, stiffness or loss of function in the osteoarthritic knee of patients with unilateral TKA. The success rate of patients with TKA in rising from a chair after surgery is lower than that of healthy individuals but higher than that of osteoarthritic patients, which supports this view.[31-33]

A significant correlation has been reported between QF muscle strength and the ability to repeat the sit-to-stand test in several studies.[34,35] Disabilities observed when rising from a chair resulting from the decrease in QF muscle strength following TKA have been reported to continue for 1 to 6 years.[9,36] The QF muscle

strength of TKA patients during the sit-to-stand test was lower than that of healthy controls but higher than that of patients with osteoarthritic knees following both unilateral and bilateral TKA.[31-33]

The rising index refers to the ratio between the force exerted by the patient on the platform during the rising activity and the patient's body weight. A lower value in TKA patients than healthy subjects is of importance as it indicates the reduction in QF muscle strength.[23] It is already known that QF muscle strength enables individuals to perform such activities as rising from a chair and walking, and in several studies it has been determined that QF muscle strength of 97% is required while rising from a chair without any support from the arms.[9,11,28,31,37] In our study, the increase in the rising index over time in patients with bilateral TKA was greater than in patients with unilateral TKA (Table 5). We believe this to be the result of functional deficits caused by the pain, stiffness, movement limitation and osteophytes in the symptomatic knee which negatively affect the rising index as well as developments in QF muscle activation. Bilateral applications allow for symmetrical knee rehabilitation.

In conclusion, weight transfer ratios were symmetrical in patients who underwent unilateral TKA during the postoperative period. Possible causes of physical performance deficiencies result from functional limitations due to pain, stiffness, and osteophytes of the osteoarthritic knee. Weight symmetry is likely to shift towards the dominant limb in patients with bilateral TKA because these patients use these extremities more. As a result, a number of complications may occur in the structure of the prosthesis due to overload on that side. We recommend that patients undergoing bilateral TKA be directed to carry out functional activities contributing to the symmetrical distribution of weight on both extremities and focus on and use the non-dominant extremity.

Conflicts of Interest: No conflicts declared.

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