Balance 1 Year After TKA: Correlation With Clinical Variables

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abstract

Knee osteoarthritis results in changes that affect balance. It has been reported that osteoarthritis worsens proprioception and increases the risk of falling. The objective of this study was to assess changes in balance among patients with knee osteoarthritis at 1 year after total knee arthroplasty (TKA) surgery and its relationship with clinical variables.

This prospective, observational study evaluated 44 patients before and 1 year after TKA. Variables analyzed included age, body mass index, pain, range of motion for both knees, bilateral quadriceps and hamstrings muscle strength, gait velocity, and Knee Society score. Balance and posture control were assessed using the following computerized posturography tests: the weight bearing test, modified Clinical Test of Sensory Interaction on Balance (mCTSIB) test, and sit-to-stand test. Pre- and postoperative differences were analyzed using Wilcoxon and chi-square tests, and effect size was measured using standardized response mean. Correlations were assessed by the Spearman test. One year after TKA, some improvement in balance tests was observed. Significant differences were observed in the mCTSIB test: foam surface with open eyes ($P<.001$), foam surface with closed eyes ($P<.001$), and composite value ($P<.001$). Effect size was moderate to high. Age showed significant correlation with mCTSIB composite value changes ($r=0.369; P=.037$). No significant correlations were found between posturographic tests and other analyzed variables.

Balance measured by computerized posturography improved 1 year after TKA. Significant changes were observed between open and closed eyes using a foam surface for the mCTSIB test. A mild negative correlation was found between age and posturographic changes.
Knee osteoarthritis is a degenerative disease that mainly affects the elderly population and brings with it a major loss of function. It is clinically characterized by pain and limited joint mobility, a decline in muscle strength, and gait changes that decrease velocity and total walking distance tolerated.

Loss of proprioception has been observed in patients with knee osteoarthritis, adding to the other debilitating factors involved in the process. Patients with knee osteoarthritis and a history of falling require more time to transfer their weight from a seated to a standing position.

The sensory systems upon which balance depends include proprioception, the vestibular system, and vision. Computerized posturography systems make it possible to obtain quantitative information about movement of the center of gravity and explore sensory inputs related to balance and the strategies that are activated to maintain posture control. Posturography studies can be static or dynamic, are done under standardized conditions, and have shown good reproducibility.

Computerized posturography has been widely used in the general population, in elderly patients, and in patients with neurological and osteoarticular diseases.

The current treatment of choice for advanced, disabling osteoarthritis of the knee is total knee arthroplasty (TKA). This procedure reduces pain and restores function. The objective of this study was to evaluate balance changes after TKA in patients with knee osteoarthritis and their relationship with the variables of age, pain, range of motion in both knees, muscle strength in the quadriceps and hamstrings, and gait velocity.

**Materials and Methods**

This prospective, descriptive, observational study included 44 patients with severe knee osteoarthritis who underwent TKA in 2006 and 2007. The study conformed to the Declaration of Helsinki and was approved by the local research ethics committee.

Inclusion criteria were patients diagnosed with knee osteoarthritis who were treated with TKA, were able to walk at least 25 meters, and provided signed informed consent. Exclusion criteria were patients with other locomotor system disorders (eg, major dysmetria, neurological deficit, malformations) or who presented sensory or cognitive impairments that would make participation difficult.

Baseline evaluation was completed at least 2 weeks preoperatively, and follow-up assessment occurred 12 months postoperatively. The following variables were collected and analyzed: age, sex, weight, height, body mass index, bilateral or single TKA, related locomotor system diseases (eg, contralateral knee osteoarthritis), date of surgery, laterality of the operated knee, type of prosthesis used, preservation or not of the posterior cruciate ligament (PCL), posterior stabilization, and intra- and postoperative complications (eg, infection, deep vein thrombosis, dehiscence, hematoma). A preoperative Knee Society score with its 2 knee and function subscores was recorded; KSS values range from 0 to 100 points, from worse to better, respectively.

At follow-up, the following data were recorded: pain severity, assessed by visual analog scale (VAS) and recorded in mm; knee range of motion measured using a lateral surface manual goniometer; muscle strength of the quadriceps and hamstrings in both legs, measured by isometric dynamometry (Nicholas Manual Muscle Tester; Lafayette Instrument Company, Lafayette, Indiana); and gait velocity, measured by the Gait Mat System II (EQ, Inc, Chalfont, Pennsylvania), a reproducible and validated instrument comprising a 4-meter-long platform with pressure sensors and a processor that interprets gait data. Each patient was asked to walk this distance 5 times at a comfortable pace.

Three posturography tests were performed with the Balance Master (NeuroCom, Clackamas, Oregon), a machine that provides an objective assessment of balance by using a forceplate to measure the vertical forces exerted by the patient’s feet and by using software to analyze the results. The weight bearing test analyzes the percentage of body weight that falls on each leg. The surgery side was taken into account in the analysis of this test. Healthy individuals maintain relatively equal body weight on each leg (within 5% in young adults and 15% in elderly adults). Unequal weight bearing outside these ranges may indicate an inability (eg, weakness or joint restriction) or unwillingness (eg, pain or anxiety) to bear weight on an affected limb, with a compensatory shift to the less affected side.

The modified Clinical Test for Sensory Interaction and Balance (mCTSIB) (Figure 1) analyzes the center of gravity movement on the plate, making modifications on the patient sensory inputs. The center of gravity movement is measured 3 times in each test, 10 seconds per trial. The amount of sway is expressed in degrees per second. The test was done on a firm surface with open eyes (using the information of all sensory systems related to balance: visual, vestibular, and somatosensory), on a firm surface with closed eyes (visual information is unavailable and somatosensory inputs are predominant), on a foam surface with open eyes (somatosensory information is available but inaccurate; to remain stable, the individual has to rely predominantly on visual inputs), and on a foam surface with closed eyes (only vestibular information is available and accurate; somatosensory information is inaccurate). This test also provides a composite of all the results. The mCTSIB test is useful for a global balance evaluation but not for an etiologic diagnosis of the impaired sensory system. Patients with musculoskeletal problems in the lower limbs may have difficulties maintaining balance and may have an abnormal score on this test, especially on the foam surface.
The sit-to-stand test measures the time that a patient needs to stand up from a chair without an armrest and the percentage of body weight that is initially mobilized. Four values were recorded: weight transfer (the time spent from initiating movement to positioning the center of gravity over both feet in a standing position), rising index (the amount of force exerted by the body during the lifting phase, expressed as a percentage of body weight), sway velocity (the velocity while lifting body weight and the first 5 seconds of the standing position), and left/right (the side to which weight bearing falls while lifting).

Beginning on postoperative day 1, all patients received 3 weeks of rehabilitation therapy, primarily consisting of mechanical movement of the knee; manual movement of the knee by the physical therapist; isometric exercises of the quadriceps, active-assisted exercises of flexoextension of the knee, and progressive muscle-strengthening exercises; gait and transfer training; and training on stairs, ramps, and obstacles. At 3 weeks, patients who had not achieved 90° of flexion or were still 15° from achieving full extension continued in outpatient therapy; those who achieved this range of motion were discharged with instructions to continue the exercises at home.

Descriptive analysis is based on the calculation of averages, SDs, medians, top and bottom quartiles, or percentages. Normal distribution of variables was analyzed using the Kolmogorov-Smirnov test and Q-Q plot. Pre- and postoperative measures were compared with Wilcoxon or chi-square tests, as appropriate. Effect size for the posturography variables that changed significantly was calculated using standardized response mean to assign a value to the differences observed: values of 0.20, 0.50, and 0.80 indicated slight, moderate, and high sensitivity to change, respectively. The presence of contralateral TKA and PCL retention vs posterior stabilization related to posturography changes were analyzed by analysis of variance. Correlations were calculated with the Spearman test. Significance was established as a \( P \) level less than .05.

**RESULTS**

Of the 44 patients (88 knees) studied, 32 (72.7%) were women. Average patient age was 71.4±7.12 years, and median age was 70.12 years (range, 66.68-76.40 years). Table 1 shows the preoperative values for the descriptive variables.

The right knee was replaced in 22 (50%) cases, all TKAs were primary, and...
the etiologic diagnosis was knee osteoarthritis in all cases. In 13.6% of cases (6 cases), the patients had already undergone contralateral TKA.

The prostheses used were Duracon (Stryker, Mahwah, New Jersey) (n=10; 22.7%), Genutech (Oribmed Advisors LLC, New York, New York) (n=15; 34.1%); Triathlon (Stryker) (n=15; 34.1%), and 913 (Exactech, Gainesville, Florida) (n=4; 9.1%). The PCL was preserved in 16 (36.4%) cases, and posterior stabilization was used in 28 (63.6%). No significant difference existed in posturography changes when comparing cruciate preservation vs posterior stabilization. No significant difference existed in posturography changes when comparing the presence or absence of contralateral TKA. Associated locomotor system disorders included contralateral knee osteoarthritis in 27 (61.4%) patients and some other type of lower-limb disorder in 10 (22.7%).

Table 2 shows the results of preoperative and 1-year postoperative measurements of gait velocity, pain, quadriceps and hamstring muscle strength, and range of motion for both knees. Significant changes occurred for the following variables: increased gait velocity, decreased pain, increased strength of the extensors in both knees, decreased flexion in both knees, and slight improvement in extension of the operated knee.

Table 3 shows the results of balance testing and the differences between preoperative and 1-year postoperative values. Significant differences existed in mCTSIB scores for the foam surface test with open eyes and closed eyes and in the composite score. The effect size of these changes was moderate to high: 0.694 (95% confidence interval [CI], 0.37-1.096), 0.74-1.0, and 1.002 (95% CI, 0.65-1), respectively. No significant differences existed in the sit-to-stand test. Age was negatively correlated with an improved mCTSIB composite score at 1 year (−0.369; P=.037), and a nearly significant negative correlation existed for

<table>
<thead>
<tr>
<th>Test</th>
<th>Median [25th-75th Percentiles]</th>
<th>Preoperative</th>
<th>1-y Postoperative</th>
<th>P</th>
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<tbody>
<tr>
<td>Weight bearing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TKA leg</td>
<td>47.50 (43.0-52.75)</td>
<td>49.0 (44.0-55.0)</td>
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<td>.157</td>
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<tr>
<td>Opposite leg</td>
<td>52.50 (48.25-57.00)</td>
<td>51.0 (45.0-56.0)</td>
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<td>.132</td>
</tr>
<tr>
<td>mCTSIB, deg/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyes open, firm surface</td>
<td>0.30 (0.20-0.40)</td>
<td>0.30 (0.20-0.40)</td>
<td></td>
<td>.846</td>
</tr>
<tr>
<td>Eyes closed, firm surface</td>
<td>0.40 (0.23-0.40)</td>
<td>0.40 (0.30-0.57)</td>
<td></td>
<td>.064</td>
</tr>
<tr>
<td>Eyes open, foam surface</td>
<td>0.95 (0.80-1.18)</td>
<td>0.90 (0.65-1.05)</td>
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<td>.000</td>
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<td>Eyes closed, foam surface</td>
<td>2.1 (1.70-2.42)</td>
<td>1.60 (1.40-1.98)</td>
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<td>Composite</td>
<td>0.90 (0.80-1.10)</td>
<td>0.80 (0.70-0.90)</td>
<td></td>
<td>.000</td>
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<tr>
<td>Sit-to-stand</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight transfer, s</td>
<td>0.53 (0.38-0.85)</td>
<td>0.49 (0.40-0.70)</td>
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<td>.104</td>
</tr>
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<td>Rising index, % weight</td>
<td>11 (6.0-14.0)</td>
<td>10.0 (8.0-13.0)</td>
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<td>.731</td>
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<tr>
<td>Sway velocity, deg/s</td>
<td>3.6 (2.70-4.60)</td>
<td>3.50 (2.90-4.60)</td>
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<td>.664</td>
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<td>Left/right, No. (%)</td>
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<td></td>
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<tr>
<td>Normal</td>
<td>29 (65.9)</td>
<td>24 (54.5)</td>
<td></td>
<td>.362</td>
</tr>
<tr>
<td>Pathological</td>
<td>13 (29.6)</td>
<td>19 (43.2)</td>
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</tbody>
</table>

Abbreviations: deg, degrees; mCTSIB, modified Clinical Test for Sensory Interaction and Balance; TKA, total knee arthroplasty.
the foam surface mCTSIB test with eyes open (−0.306; P = .061) (Figure 2).

Preoperatively, a significant correlation was observed between the sit-to-stand rising index and muscle strength in the operated limb, in both the quadriceps (0.355; P = .026) and hamstrings (0.391; P = .014): the greater the quadriceps or hamstrings muscle strength, the higher the rising index. Likewise, a positive correlation was found between the preoperative rising index and gait velocity (0.376; P = .017): the higher the velocity, the better the rising index scores.

No correlation was found among preoperative body mass index, weight, height, and KSS or among changes in posturography tests. Changes in posturography test values 1 year postoperatively were not significantly correlated with objective changes in the variables of pain, knee range of motion, muscle strength, and gait velocity.

No significant difference existed in posturography changes when comparing cruciate preservation vs posterior stabilization. No significant difference existed in posturography changes when comparing the presence or absence of contralateral TKA.

**DISCUSSION**

In this study, balance improved significantly 1 year after TKA compared with preoperative values. This improvement was noted in the foam surface mCTSIB test with open and closed eyes, as well as in the composite mCTSIB score. Age was negatively correlated with the increase in composite mCTSIB score: the older the patient, the less the score improved. No significant changes were observed in the weight-bearing and sit-to-stand tests.

Other authors have reported improvements in balance after TKA, although their results are difficult to compare with the current results due to differences in research design, methods, tests, and length of follow-up. Bakirhan et al. conducted a posturography study using the Balance Master system at 6 and 12 months after TKA. They reported significant changes in the dynamic limits of stability test but not in the mCTSIB test. They concluded that these changes were due to improved proprioception after TKA.

Swanik et al. observed significant improvement in balance on an unstable platform between preoperative and 6-month follow-up values. They also observed improved proprioception and kinaesthesia.

The current study also showed improved balance 1 year after TKA. Beyond the statistical significance, the standardized response mean, a statistic based on effect size, was calculated to measure the change and express the variability of the change scores. Based on the SRM, the perceived change was adjusted for the foam surface with eyes open mCTSIB score (0.694), the foam surface with eyes closed mCTSIB score (1.096), and the composite mCTSIB score (1.002). Assuming no substantial change existed in the visual or vestibular component of balance during the follow-up period, these changes would be attributable to elements that affect proprioception. According to Swanik et al., post-TKA changes could affect the response of mechanoreceptors in the capsuloligamentous and musculotendinous structures, improving proprioception. Another factor that must be taken into account is physical therapy, which could contribute to improving function.

The role of PCL retention in TKA results remains controversial. In a randomized, prospective bilateral TKA study comparing PCL retention with PCL substitution in the same patient, Kim et al. reported no differences in knee rating systems, range of motion, Western Ontario and McMaster Universities Osteoarthritis Index, patient satisfaction, and radiographic results. However, in a similar randomized bilateral TKA study, Yagishita et al. reported significantly better range of motion, patient satisfaction, and posterior knee pain in passive flexion results for a cruciate-substituting design. In the current study, no differences existed between groups with or without PCL retention in terms of posturography changes at 12-month follow-up. These results agree with those reported by Swanik et al., who assessed balance in TKA patients using an unstable platform preoperatively and 7.6 months postoperatively. They compared a cruciate-retaining design with a posterior stabilized design and reported no significant difference in balance between the groups.
Simultaneous bilateral TKA has shown better functional long-term outcomes compared with unilateral TKA and staged bilateral TKA. Bakrhan et al compared unilateral with bilateral TKA and reported no significant difference between groups in terms of mCTSIB in postoperative months 6 and 12. In the current study, no was observed in posturography changes between patients undergoing unilateral TKA and those undergoing staged bilateral TKA; however, only 6 patients underwent bilateral TKA, so these results should not be considered generalizable.

A negative correlation existed between improved balance 1 year after TKA and patient age (composite mCTSIB). This result agrees with other studies in which the sensorimotor system of the study population decreased with age. Nonetheless, the senile population maintained a certain capacity for change in their reflex responses, which allows people of this age to achieve adaptive responses through balance training.

The current study found no significant changes in the sit-to-stand test between the preoperative and 1-year postoperative scores. Su et al used the ExpertVision movement analysis system (Motion Analysis, Santa Rosa, California) (with 6 cameras and 2 force plates [Type 9281B; Kistler Instrument, Winterthur, Switzerland]) to analyze differences between 3 groups of patients standing from a chair: those with knee osteoarthritis, those with TKA implants 2 to 6 years postoperatively, and healthy elderly individuals. The osteoarthritis and TKA groups took longer to complete this movement than the healthy group. The authors reported that the patients with osteoarthritis, whether operated on or not, used compensatory mechanisms, such as leaning farther forward and transferring more weight to the healthy side of the body. In the current study, weight transfer in the sit-to-stand test was within normal parameters for most patients (54.5%); Patients with non-normal weight transfer showed no single pattern: some shifted more weight to the prosthesis side, others to the contralateral limb. However, difficulties in standing from a chair have been reported when the extension force of the knee is less than 10 kg. The sample in the current study had an average preoperative muscular balance in the quadriceps of 20.33 kg, which increased significantly to 25.31 kg, putting them well above this threshold. Nonetheless, a moderately positive correlation existed preoperatively between the rising index score and muscle strength of the quadriceps and hamstrings muscles. Likewise, the preoperative rising index score was correlated with gait velocity.

No significant correlations existed between preoperative values for gait velocity, pain, knee range of motion, or muscle strength and any of the posturography parameters studied. No significant correlations existed between changes in these variables at 12 months and those observed in balance tests.

Limitations of this study included the small sample size and the lack of a control group.

**CONCLUSION**

This study found improved balance 1 year after TKA. This improvement was reflected in the mCTSIB scores from posturography testing on a foam surface.

**REFERENCES**


