Unipedal Balance Is Affected by Lower Extremity Joint Arthroplasty Procedure 1 Year Following Surgery

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ABSTRACT

Lower Extremity Joint Arthroplasty (LEJA) surgery is an effective way to alleviate painful osteoarthritis. Unfortunately, these surgeries do not normalize the loading asymmetry during the single leg stance phase of gait. Therefore, we examined single leg balance in 234 TJA patients (75 hips, 65 knees, 94 ankles) approximately 12 months following surgery. Patients passed if they maintained single leg balance for 10 s with their eyes open. Patients one year following total hip arthroplasty (THA-63%) and total knee arthroplasty (TKA-69%) had similar pass rates compared to a total ankle arthroplasty (TAA-9%). Patients following THA and TKA exhibit better unilateral balance in comparison with TAA patients. It may be beneficial to include a rigorous proprioception and balance training program in TAA patients to optimize functional outcomes.

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Osteoarthritis of the hip, knee or ankle is a progressively debilitating disease that often progresses to severe pain that has been associated with decreased balance, motion, and muscle activation [1,2]. Patients with end-stage osteoarthritis have a loss of cartilage and mechanoreceptors, joint laxity, and significant inflammation resulting in reduced proprioception and postural balance feedback [3,4].

When patients with end-stage lower extremity osteoarthritis fail conservative measures such as analgesics, walking aids and lifestyle modifications, the most common treatment is a lower extremity joint arthroplasty (LEJA). Joint arthroplasty of the hip, knee or ankle for the treatment of end-stage osteoarthritis is one of the most common, successful and increasingly popular procedures in healthcare, providing patients with rapid and substantial decrease in pain [5–9]. Furthermore, several reports have concluded that LEJA can partially restore joint sensation and motion, enhancing motor coordination, functional stability, and proprioception [3,10–14]. However, like any surgical procedure, LEJA is not without complications. Common complications reported after total hip arthroplasty (THA) include dislocation, abductor weakness, decreased range of motion, and a limp [15–19]. Similarly, common limitations reported after total knee arthroplasty (TKA) include

diminished walking speed, difficulty ascending and descending stairs, and inability to return to sports played prior to surgery with up to 37% of patients reporting limited function post-operatively [20–23,9]. Common problems reported after total ankle arthroplasty (TAA) include residual pain, superficial wound complications, and deep infections as well as limitations in walking speed and gait mechanics [24,25]. These limitations have been attributed in part to deficits in balance, proprioception, muscle strength and postural control [13,3,10,26–31].

Maintaining balance is a complex process in which neurophysiological and environmental factors interact [32]. Maintaining balance is required when switching from bilateral to unilateral standing for many activities of daily living such as walking, turning, climbing stairs, and dressing [33]. Gait analysis and balance assessments are commonly performed in TJA patients, and are critical for identifying potential impairments and falls risk [34–37]. However, no reports have been identified, to date, that examine how isolated single leg stance ability is altered following TJA.

Due to the limitations of the current literature, the purpose of the current study was to discover whether a fundamental difference existed in the unilateral stance ability of LEJA patients following surgery. The single-leg stance (SLS) test was used because it is readily accessible to clinicians and provides a quantitative assessment of balance [38,34,39]. The SLS test measures the time one is able to stand on one limb without support, while barefoot and with eyes open [38]. Due to a lack of previous research in this area, we hypothesized that all lower extremity joint arthroplasty categories (THA, TKA and TAA) would have similar performance on single leg balance testing, and that there would be significant

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Table 1
Patient Demographics Based on Type of Arthroplasty.

	THA	TKA	TAA	P Value
Age (y) ^a	66.1 ± 9.6	61.8 ± 9.5	64.8 ± 9.5	0.55
Height (m) ^a	1.73 ± 0.10	1.67 ± 0.11	1.69 ± 0.12	0.07
Weight (kg) ^a	87.4 ± 25.5	90.8 ± 25.9	80.7 ± 16.9	0.33
BMI (m/kg ²) ^a	31.0 ± 7.0	28.1 ± 6.1	29.2 ± 6.1	0.03

^a Values presented as mean ± SD.

surgical to non-surgical differences in SLS time for all joint arthroplasty categories 1-year following surgery based on the known deficits and asymmetries that have been reported during walking following LEJA.

Methods

This retrospective study was granted approval from our Institutional Review Board. A total of 234 TJA patients from a single institution participated in this study (Table 1). Inclusion criteria consisted of adult patients who had a unilateral THA, TKA or TAA, had a LEJA at least one year prior to study enrollment, had no pain or diagnosed osteoarthritis in any other lower extremity joint, and were not currently using an assistive device for ambulation. Exclusion criteria consisted of contralateral lower extremity joint pain, diagnosed contralateral lower extremity joint degeneration, a history of contralateral lower extremity joint arthroplasty or spinal surgery, or a history of significant neurologic or vestibular disorders that affected balance, gait and activities of daily living. Eligible candidates were recruited at their 1-year postoperative visit from the orthopedic clinic at the university. Testing was performed following informed consent, which was approved by the medical center's institutional review board. All patients had completed the physical rehabilitation protocols which were standardized across surgeons for a specific LEJA procedure.

The single-leg balance assessment required patients to maintain unilateral balance without assistance for 10 s on their surgical and non-surgical limbs while barefoot and with eyes open on a firm surface. Patients were allowed to move their upper extremities for balance, but the assessment was stopped if the elevated limb touched the floor, the other limb was being used to aid in balance, or they required assistance for balance. The subject was determined to have passed (pass) the test if he/she was able to maintain unilateral stance on both the surgical and non-surgical sides for 10 s. Those that failed the SLS test had stance time recorded bilaterally. Three trials were performed per lower extremity. The decision was made to use 10 s to indicate successful unilateral balance because it is a time-efficient measure that can be performed in high-volume clinics. Five seconds has been suggested as a single leg stance time criterion standard, however this is noticeably lower than age matched controls (17.1–24.3), thus as a result a higher standard of 10 s was selected for the cut-off in the current study [40,41,33,42].

Statistical analyses were conducted using a Chi-Square to examine the pass:fail ratio across the different total joint surgeries. A-priori it was anticipated that BMI would have a significant role in the outcome in the study and as a result the effect of BMI on single leg balance was isolated for analysis. An initial analysis was completed on the dataset to examine the effect BMI level has on the pass:fail ratio for each of the different LEJA procedures. In patients who failed the test, a 2 × 3 (side × surgery) ANOVA was used to determine if there were significant differences in unilateral balance symmetry across the types of surgery (THA, TKA, TAA). Tukey HSD was conducted for post-hoc testing when appropriate. Statistical significance was established at $P < 0.05$ for all analyses.

Results

A total of 75 THA patients, 65 TKA patients, and 94 TAA patients participated in the study (Table 2). No significant differences existed in

Table 2
Single-Leg Stance Test Pass Rate and Times per Limb for All Patients per LEJA Group That Failed Single Leg Stance.

	THA	TKA	TAA
Patients (n)	75	65	94
SLS Pass Rate (%)	63	69	9
SLS Time (s) ^a			
Surgical	3.3 ± 2.8	4.4 ± 3.8	3.2 ± 2.7
Non-Surgical	5.3 ± 3.4	5.7 ± 3.7	6.3 ± 4.1

^a Values for SLS Time presented as mean ± SD.

height, weight, or age between the THA, TKA, and TAA patient groups (Table 1). BMI was observed to be elevated in the THA sample compared to the TKA (-2.9 kg/m^2) and TAA (-1.7 kg/m^2).

BMI was not observed to have a significant effect on the ability to pass the single leg stance clearing test. Patients who underwent a THA procedure, had 1.4× as many patients pass the test if they had a low (<30) BMI while 2× as many patients passed if they were in the high (>30) BMI group. Similar results were observed for the TKA group, with 2.5× as many individuals passing in the low BMI group and 2.1× as many individuals completing the test in the high BMI group. For the TAA subjects, 7% of the low BMI group passed and 12% of the high BMI group passed. The differences in percentages between low and high BMI groups were not statistically significant across all of the different lower extremity arthroplasties.

Pass:fail rates on the single leg balance test were observed to differ based upon which joint was replaced. Patients at 1-year following THA and TKA passed the single-leg balance assessment at a similar rate, 63% (47/75) and 69% (45/65), respectively (Table 2). The rates in TKA and THA greatly differed from the TAA sample, who exhibited a noticeably lower pass rate of 9% (8/94). Significant differences in rates were observed between THA/TKA and TAA but not between THA and TKA.

For those individuals who did not pass the single leg stance test, a significant interaction ($P < 0.01$) was found for unilateral balance between the surgical and non-surgical sides across the different surgeries. This finding suggests that the surgical and non-surgical limb response varied depending on the LEJA. Patients following THA and TKA were more symmetrical between surgical and non-surgical sides than the TAA patients (Table 2). On average, a 1.6-s reduction in stance time on the surgical side was observed across TJA groups in patients who failed the SLS test (Table 2). For the THA patients, the SLS time (mean ± SD) on their surgical limb was 3.3 ± 2.8 s, while it was 5.3 ± 3.4 s on their non-surgical limb (Table 2). SLS time (mean ± SD) in TKA patients on their surgical limb was 4.4 ± 3.8 s, while it was 5.7 ± 3.7 s on their non-surgical limb (Table 2). For TAA patients, SLS time (mean ± SD) on their surgical limb was 3.2 ± 2.7 s, while it was 6.3 ± 4.1 s on their non-surgical limb (Table 2).

Discussion

Lower extremity joint arthroplasty is an effective procedure that significantly alleviates the pain associated with end-stage osteoarthritis [6,9,8,5,7]. The alleviation of pain following surgery is thought to be associated with improvements and normalization of function, however; to date there are few standards established in order to assess the normalization of function. In selecting a test for balance, we wanted to use a valid clinical tool that was commonly used, readily accessible without use of special equipment, is inexpensive, time-efficient, and easily performed during a clinic visit. The SLS test was selected based on the common use of the test and the reliability of the test among physicians and physical therapists as well as its well-documented use in a variety of clinical settings [34,38,43]. Performance on the test has been shown to exhibit discriminatory validity in high-functioning older adult populations related to fall risk and independence in activities of daily living [44]. To date, no study has utilized this metric to examine

outcomes in lower extremity joint arthroplasty patients, which was the primary aim of this study.

In our study, patients following THA and TKA exhibited better unilateral balance with less difference between surgical and non-surgical sides in comparison with TAA patients. This finding was contradictory to our hypothesis which expected the groups to perform at a similar level. These findings may be associated with the increased role of the ankle in balance and proprioception or may be associated with differences in post-operative disability between the surgical populations. Little research has been done on single leg stance following LEJA. Szymanski et al studied functional performance in a group of THA patients compared to a hip resurfacing group and controls [45]. The study reported that only 25% of THA patients, compared to 100% of resurfacing patients and 100% of healthy controls, were able to complete a 25 s SLS test on the surgical and non-surgical side. Our results are similar to those published by Lee et al, who studied postural balance in 30 healthy controls and 30 TAA patients at least one year following surgery [36]. TAA patients demonstrated decreased postural stability when compared to controls. The results by Lee et al could indicate that TAA patients have poorer reciprocal sagittal plane coordination at the ankle, which likely has a significant impact on activities of daily living.

While research has previously observed balance deficits in TJA patients compared to controls, this is the first study we are aware of to make comparisons between patients receiving hip, knee and ankle LEJA. These findings may suggest a need for altered rehabilitation strategies in each post-operative population, particularly in the area of balance training, in order to normalize function following LEJA.

Based on the results of this study it appears that single leg stance is limited up to one year following LEJA and could be an appropriate clinic based assessment to determine functional status and recovery following surgery. While single leg stance is limited following surgery, the question of how to improve performance on these measures remains. Recent research has studied how exercise programs including functional training and balance can improve single leg stance. Piva et al examined whether a functional training program alone (FT group) or with a balance exercise program (FT + B group) could improve single leg stance performance in TKA patients at least 2 months out from surgery [46]. The FT group had mean preoperative SLS times of 11.7 ± 11.9 s and 11.0 ± 10.8 s on the surgical and non-surgical sides, respectively, while the FT + B group exhibited times of 16.4 ± 10.9 s and 11.0 ± 10.0 s on the surgical and non-surgical sides, respectively. Interestingly, at the 6-month follow-up, participants in the FT + B group could balance an average of 4 s longer than the baseline measurement on each leg, while the FT group only returned to baseline in the surgical side and improved their SLS time by 2 s in the non-surgical side. Similarly, it has been shown that conditioning exercises like Tai-Chi and yoga improve SLS times; however these exercise forms have not been studied in TJA patients [43]. It may be that a functional balance training program could be implemented as part of the home exercise program in addition to traditional rehabilitation in order to normalize single leg balance with the aim of improving patient function following LEJA.

Our study does have several limitations. First, we did not collect pre-operative SLS times. As a result, we are unable to examine the effectiveness of the LEJA on SLS performance. Second, given the wide variety of surgical techniques and implants used, it is impossible to determine from our data if either of these factors had a significant effect on SLS time. Third, although all of our patients underwent the current physical rehabilitation standards for their respective type of arthroplasty, we did not

account for any other types of physical activity undertaken postoperatively that could have influenced single leg stance time. Finally, there was no stratification based on comorbidities beyond the exclusion criteria which may have affected the results of the study.

In summary, one year following surgery, THA and TKA patients exhibit better unilateral balance than TAA patients. This finding potentially indicates the importance of the ankle in maintaining balance and may be an important function to normalize postoperatively. In addition, it is important to understand that 30% of THA and TKA patients did not pass the 10 s single leg stance test, which is well below the 25 s single leg stance time for normal, healthy individuals in this age group (Table 3) [42]. Future studies in this area could examine single-leg balance as a clinically relevant screening tool for unilateral functional outcome after LEJA as well as intervention models to integrate into the plan of care with the aim of normalizing single leg balance following LEJA.

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Table 3
Single-Leg Stance Times With Eyes Open per Patient Age [38].

Age (y)	Studies/Groups	# of Patients Studied (n)	Mean SLS Time (95% CI)
60–69	11/14	851	27.0 (20.4–33.7)
70–79	12/17	870	17.2 (11.6–22.8)
80–99	6/6	146	8.5 (1.0–16.1)

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