Original Research

# The Effect of Prehabilitation Exercise on Strength and Functioning After Total Knee Arthroplasty

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**Objective:** The purpose of this study was to examine the effect of a preoperative exercise intervention on knee pain, functional ability, and quadriceps strength among patients with knee osteoarthritis before and after total knee arthroplasty (TKA) surgery.

**Design:** A repeated-measures design was used to compare 2 groups over 4 data collection points.

**Setting and Patients:** Community-dwelling subjects with osteoarthritis of the knee who were scheduled for a unilateral TKA were recruited from a single orthopedic surgeon's office and were randomized into control (n = 28) or prehab groups (n = 26).

**Interventions:** The control patients maintained usual care before their TKA. The exercisers performed prehabilitation exercises, which included resistance training, flexibility, and step training, 3 times per week before their TKA.

**Outcome Measures:** Knee pain, functional ability, quadriceps strength, and strength asymmetry were assessed at baseline (T1), at 1 week before the patients' TKA (T2), and again at 1 (T3) and 3 (T4) months after TKA.

**Results:** The exercisers improved their sit-to-stand performance at T2, whereas the control group did not change their performance of functional tasks and had increased pain at T2. At T3 the exercisers demonstrated improved sit-to-stand performance. The control patients at T3 exhibited decreases in pain, their 6-minute walk, surgical leg strength and an increase in their nonsurgical leg strength and leg strength asymmetry. At T4 the exercisers improved in their performance of 3 of the 4 functional tasks, decreased all of their pain measures, and increased their surgical and nonsurgical quadriceps strength. At T4 the control group improved their performance on 2 of the 4 functional tasks, decreased all of their pain measures, increased their nonsurgical leg strength, and exhibited greater leg strength asymmetry.

**Conclusion:** These findings appear to indicate the efficacy of prehabilitation among TKA patients and support the theory of prehabilitation.

## INTRODUCTION

Osteoarthritis (OA) is one of most common chronic health problems, affecting more than 7 million Americans [1], with 59% of adults older than 65 years of age affected by this disease [2]. Characteristics of knee OA include decreases in strength and functional ability and increases in joint pain [3]. Knee OA is initially treated pharmacologically in an attempt to control the joint pain and preserve functional ability. Despite these treatment attempts progression of knee OA and functional decrease require many patients to undergo total knee arthroplasty (TKA) [4]. TKA involves removal of the OA-diseased knee joint, which is replaced by a prosthetic device and commonly involves prolonged rehabilitation [4,5]. On the basis of existing research evidence, total knee replacement is a safe and cost-effective treatment for alleviating pain and restoring physical function in patients who do not respond to nonsurgical therapies. There are few contraindications to this surgery as it is currently used [6]. More than 381,000 TKA procedures are performed in the United States annually [5], and this number is predicted to increase by 600% to more than 3.4 million cases by 2030 [7].

Preoperative measures of strength, functional ability, and knee pain have been shown to be significant predictors of outcomes after TKA. Other investigators have observed that

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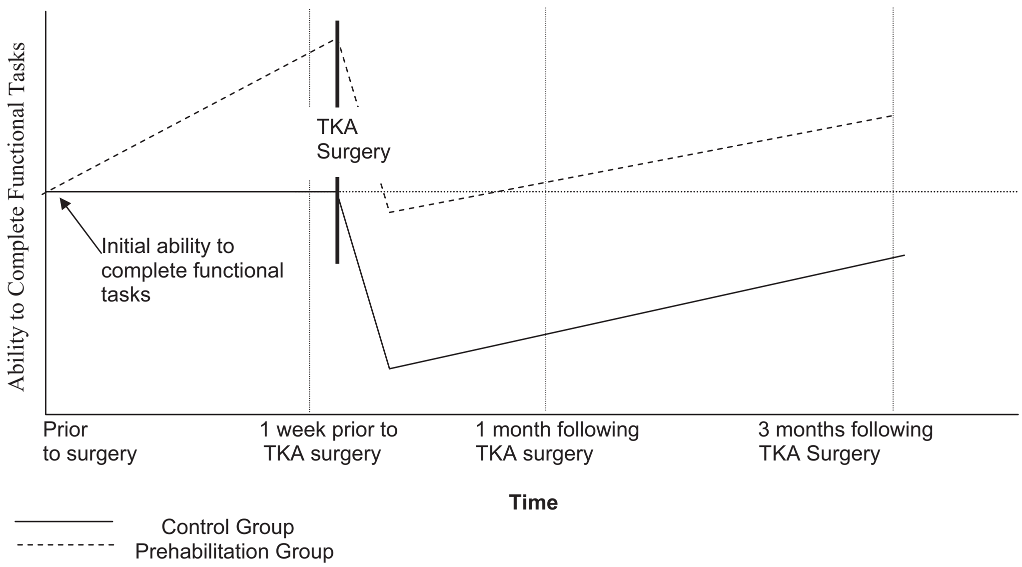


**Figure 1.** Theoretical model of the effect of prehabilitation on the ability to complete functional tasks among TKA patients.

preoperative knee flexibility, pain, and functional ability significantly predicted postoperative flexibility, pain, and functional ability respectively among patients undergoing TKA [8,9]. Sharma et al [10] reported that functional ability 1 month before a TKA predicted functional ability 3 months after the procedure. Similarly, Lingard et al [11] reported postoperative functional ability up to 2 years after a TKA was predicted by preoperative knee pain and functional ability. In an earlier study, Escalante and Beardmore [12] attempted to identify predictors of length of hospital stay after TKA and total hip replacement surgeries. They concluded that interventions, which optimize preoperative functional ability among TKA and hip replacement patients, could potentially enhance postoperative functional ability and decrease postoperative hospital stay.

Studies that have attempted to examine the effect of presurgical exercise on postsurgical recovery among TKA patients have been inconclusive. Jones and Blackburn [13] stated in an early opinion article that a TKA patient's ability to physically participate in his or her rehabilitation after TKA is an important predictor of success with rehabilitation. Rooks et al [14] reported that a 6-week presurgical exercise program can safely improve preoperative functional status and muscle strength levels in persons undergoing total hip arthroplasty and TKA. Additionally, exercise participation before total joint arthroplasty dramatically reduced the need for extensive inpatient rehabilitation [14].

However, other investigators have reported limited benefits of preoperative exercise on postoperative functioning among patients undergoing TKA. Weidenhielm et al [15] reported that preoperative physiotherapy had no significant postoperative effect and, in fact, patients who received preoperative physiotherapy showed a decrease in strength 3 months after the surgery. Rodgers et al [16] examined the effect of 6 weeks of physical therapy, 3 times per week, among 10 subjects scheduled for TKA and reported no effect of this intervention on preoperative or postoperative strength. Beaupre et al [17] reported that a 4-week preoperative physical therapy and education program resulted in no differences in knee pain, function, or health-related quality of life after the intervention program at any postoperative measurement point. Patients in the treatment did trend toward the use of fewer postoperative rehabilitation services and stayed for a shorter time in hospital compared with the control group. In a similar study, D'Lima et al [18] examined the effect of strength or aerobic training versus a control condition among 30 patients scheduled for TKA. These authors reported no effect of either of the 2 modes of preoperative exercise training over the control condition on self-reports of strength or functional ability. These previous studies were likely limited by small sample sizes, resulting in low statistical power, inadequate exposure to exercise training, and a lack of specificity of the training to impact the outcome measures.

The theory of prehabilitation supports the positive hypothesized effects that training before TKA may have upon postoperative knee pain, functional ability, and quadriceps strength (Figure 1). Prehabilitation is broadly defined as improving the functional capacity of an individual through physical activity to withstand a stressful event [19,20]. Individuals with OA of the knee commonly present with knee pain, and decreased functional ability and quadriceps strength [21,22]. Quadriceps strength has been shown to be inversely related to knee pain and a direct predictor of functional ability among patients with knee OA [23]. Further, patients with knee OA, even those with severe disease, have demonstrated they can reduce their knee pain, improve their quadriceps strength, and improve their functional ability through regular exercise training [20,24,25].

Commonly, a patient with knee OA presents for TKA surgery with low functional ability and reduced quadriceps strength, which likely contributes to lower functional ability and quadriceps strength after the TKA. If the patient undergoing TKA could improve his or her functional ability and quadriceps strength while decreasing knee pain before the TKA, the theory of prehabilitation predicts the patient will present during the postoperative period with greater quadriceps strength and functional ability that would logically result in accelerated progress of his or her rehabilitation. Therefore, it seems appropriate to attempt to enhance an individual's quadriceps strength and functional ability before encountering the stressor of TKA surgery through prehabilitation.

The purpose of this study was to examine the effect of a preoperative prehabilitation exercise intervention on knee pain, functional ability, and quadriceps strength among patients with knee OA before and after their TKA surgery. This purpose was examined through addressing 2 hypotheses: One, patients with OA who complete a prehabilitation program before TKA surgery will exhibit decreased knee pain, improved functional ability, and improved quadriceps strength *before* their TKA; and two, patients with OA who complete a prehabilitation program before TKA surgery will exhibit decreased knee pain, improved functional ability, and improved quadriceps strength after their TKA.

## METHODS

Participants in this trial were recruited through a single orthopedic surgeon's office. Although this practice limited external validity, subjects were recruited from this single surgeon's practice in an attempt to minimize the potential confounding effects of varying surgical techniques and preoperative/postoperative staff and care protocols. Subjects were older than 50 years of age, were scheduled for a unilateral TKA, and did not meet standard exclusion criteria for engaging in moderate intensity exercise [26]. The single orthopedic surgeon used a standard anterior surgical approach to the affected knee with separate prosthesis affixed to both the femur and tibia while preserving the collateral ligaments and when possible preserving the posterior cruciate ligament. No resurfacing of the patella was performed. The subject completed an informed consent, which was approved by the University's Human Studies Committees before any data collection took place. A total of 54 subjects were consecutively entered into the 5-month protocol. These individuals were randomly assigned at baseline to a usual-care group (n = 28) or a prehabilitation intervention group (n = 26). All health-care staff involved with the pre-, intra-, and postoperative care of the subjects was blind to subject's study group assignment.

After the TKA surgery all subjects participated in the same postoperative rehabilitation protocol. This protocol emphasized and assessed the following functional tasks: including ambulation, negotiating stairs, and transferring from a bed to sitting and from sitting to standing positions. The protocol included straight leg raises, knee extensions with and without weights, continuous progressive movement, and flexibility exercises. After discharge all subjects were prescribed up to 9 in-home sessions with a visiting physical therapist until they achieved 0-100° of range of motion on their surgical knee. Participants completed 4 data collection appointments; at baseline upon entry into the trial at a minimum 4 weeks before their surgery (T1), at 1 week before their TKA (T2), and at 1 (T3) and 3 (T4) months after their TKA. Three to 6 months after a TKA is a standard assessment point to determine the effectiveness of the surgery [10,27,28]. The same data were collected at each of these data collection appointments consisting of the participant's knee pain, functional ability, and quadriceps strength.

Knee pain was assessed in the knee undergoing surgical intervention by the use of a 10-cm visual analog scale (VAS) completed by each subject immediately after completion of each of the functional tasks used to assess functional ability. Subjects were requested to indicate on the VAS the severity of knee pain they experienced in the knee undergoing surgical intervention while performing each of the functional tasks. The VAS was anchored at the terminal points of the scale by the terms "no pain" and "extreme pain." The VAS has been demonstrated to correlate well [29] with physician assessments of pain ($r = .70$), and to have high test-retest reliability ($r = .97$) [30].

Functional ability was assessed by the subject's ability to complete 4 functional tasks. Performance of functional tasks was used to operationalize functional ability instead of various self-report instruments because actual performance of functional tasks is used by clinicians to measure patient progression. The first functional task assessed was the distance covered in a 6-minute walk. Previous investigators have assessed the functional ability of TKA patients before and after surgery by using this protocol, with minimal reports of injury [31,32]. Each subject was instructed to cover as much distance as possible within 6 minutes while walking around an indoor 36-meter oval course, which was marked off in 1-meter increments. Subjects were instructed that they could stop at any point during the test if they experienced fatigue or pain and could resume walking once they felt capable of continuing. At the end of the 6 minutes, the total distance walked in meters was recorded.

The second functional tasks involved the number of sit-to-stand repetitions the subject could complete in 30 seconds. Each subject began this assessment seated on a padded 68-centimeter high bench, which had no arms or back. Each subject assumed an upright standing position followed by a seated position as many times as possible within a 30-second time interval. The number of complete stands (up from and then down to the bench) was recorded. This assessment has demonstrated high validity by being correlated with a one repetition-maximum leg press ($r = .78$ men/$r = .71$ women) and strong test-retest reliability ($r = .89$) [33].

After the assessment of these first 2 functional tasks, subjects were instructed to ascend a flight of 22 stairs (step height = 18 cm). After ascending these stairs, the subject was

**Table 1.** *Characteristics of the Prehab (n = 26) and Control (n = 28) groups*

| | Prehab | Control | Statistical Comparison |
|---|---|---|---|
| Gender | | | |
| Men | 7 (27%) | 10 (36%) | $\chi^2$ = .24 |
| Women | 7 (27%) | 10 (36%) | $P < .63$ |
| Age | 64.1 ± 7.05 | 63.5 ± 6.68 | *t* test = .31, $P < .76$ |
| Body mass index | 32.16 ± 5.87 | 32.00 ± 6.09 | *t* test = .49, $P < .78$ |
| Prehab intervention sessions | 13.04 ± 7.5 | NA | NA |

instructed to rest 30 seconds and then descend these same stairs. The test began with the subjects standing and facing the stairs with their hands at their sides. Subjects were instructed that they could use the handrails if necessary to maintain their balance and safety while ascending or descending the stairs. The times to complete both the first and second flight of stairs were recorded. Completion of a flight was determined when both feet arrived on the final stair. Previous authors reported a high degree of sensitivity of this assessment to exercise training among knee OA patients and functionally limited older adults [34,35].

Quadriceps strength was measured bilaterally by the use of a Biodex System 3 Version 3.30 dynamometer (Biodex Medical Systems, Inc., Shirley, NY). The protocol used was similar to that developed by Topp and Mikesky [36], which was adapted from Elsner et al [37]. Knee movement was isolated through the use of Velcro straps on the trunk, waist, and thigh. Quadriceps strength was assessed through 3 repetitions of knee extension at maximal exertion from 90° to 0° of knee flexion with each trial separated by a 10-second rest period. The dynamometer was set to resist each motion at 60°/s. Subjects were informed of the purpose of the test and given an opportunity to become familiar with the testing equipment. Reliability of an isokinetic dynamometer by use of a similar protocol has been found acceptable for determining strength among older adults (r = .91–.94) [37]. The peak torque/body weight (kg) of all 3 trials was recorded for maximum quadriceps strength of the surgical and nonsurgical leg, with the greatest measure for each motion used for statistical analysis. A strength asymmetry score was calculated by subtracting the surgical leg strength measure from the nonsurgical leg strength measure at each data collection point. Greater asymmetry values indicated the nonsurgical leg was relatively stronger than the surgical leg.

After T1 data collection, subjects were randomized into either a control (Control) or prehabilitation intervention group (Prehab). Subjects assigned to the Control group were asked to continue their normal activities until their TKA. Subjects assigned to the Prehab group were asked to participate in a minimum of 3 prehabilitation sessions per week. One of these 3 weekly sessions was conducted under the supervision of the research personnel, whereas the other 2 weekly sessions were conducted by the subject in their home. After T1, subjects in the Prehab group were taught each exercise and were instructed how to conduct each intervention session. Each intervention session emphasized the following 3 exercise components: resistance training, flexibility, and step training, which have been presented previously in the literature [38].

Subjects documented their compliance with the prehabilitation treatment by using an exercise log. A single intervention session started with a 5-minute warm-up consisting of light walking. The warm-up was followed by 9 lower body resistance training exercises, including squats, hip flexion and extension, hip abduction and adduction, ankle plantar flexion and dorsiflexion, and knee extension and flexion. Each of these resistance exercises incorporated various intensity levels of Thera-Band bands (Hygienic Corporation, Akron, OH). After completing the resistance exercises, subjects performed a series of forward and lateral step training exercises up and down a standard 8-inch step. Each intervention session was concluded with a cool-down of light static stretching that included gluteus, hip, hamstring, calf, torso, upper back, lower back, and triceps stretches followed by 5 minutes of light walking. The number of prehabilitation sessions each intervention subject completed was variable because the duration of time available before the subject underwent TKA varied by the surgeon's availability to do the surgery.

## Analysis

Data analysis to address the hypotheses consisted of repeated-measures analysis of variance to determine a time effect or if the study groups changed their knee pain, performance of functional tasks, or quadriceps strength over the duration of the study. After the detection of a significant time effect ($P < .05$), Tukey least significant difference post-hoc tests were used to identify within-group differences from baseline measures over the duration of the study ($P < .05$).

# RESULTS

Of 54 subjects completing the trial, 37 (68%) women and 17 men (32%) were equally distributed between the groups (Table 1). The average age and body mass index of the sample were approximately 64 years and 32 kg/m$^2$, respectively. Subjects in the Prehab group recorded completing an average of 13.04 intervention sessions with a range of 4 to 23 sessions between T1 and T2 before their TKA.

Table 2 presents changes in knee pain, performance of functional tasks, and leg strength within the study groups over the duration of the study. At T2 the Prehab group significantly increased their ability to complete sit-to-stand maneuvers and indicated a nonsignificant trend toward im-

**Table 2.** *Changes in functional ability, pain, and knee extension strength of Prehab (n = 26) and Control (n = 28) groups over the duration of the study*

| | | | T1 Baseline | T2 Before Surgery | T3 1 Month After Surgery | T4 3 Months After Surgery |
|---|---|---|---|---|---|---|
| Sit-to-stand | Repetitions in 30 seconds | Prehab | 10.39 ± .72 | 12.08 ± .83* | 11.46 ± .69* | 12.87 ± .82* |
| | | Control | 9.79 ± .69 | 9.82 ± .80 | 10.36 ± .67 | 11.25 ± .79* |
| | Pain | Prehab | 3.96 ± .45 | 4.03 ± .46 | 2.20 ± .39 | 1.62 ± .29† |
| | | Control | 4.13 ± .44 | 4.91 ± .45 | 2.04 ± .37* | 1.06 ± .28† |
| 6-minute walk | Distance (m) | Prehab | 1254 ± 64 | 1282 ± 59 | 1191 ± 51 | 1337 ± 58 |
| | | Control | 1237 ± 62 | 1185.18 ± 56 | 1166.71 ± 49† | 1365 ± 56* |
| | Pain | Prehab | 4.22 ± .43 | 4.77 ± .45 | 2.17 ± .37 | 1.53 ± .34† |
| | | Control | 5.20 ± .41 | 6.80 ± .43* | 2.36 ± .35† | 1.38 ± .33† |
| Ascend stairs | Time (s) | Prehab | 11.22 ± 1.06 | 10.63 ± 1.12 | 11.98 ± 1.36 | 8.44 ± .81* |
| | | Control | 9.78 ± 1.02 | 10.36 ± 1.08 | 10.39 ± 1.31 | 7.45 ± .77 |
| | Pain | Prehab | 3.85 ± .49 | 4.34 ± .51 | 2.03 ± .37 | 1.33 ± .31† |
| | | Control | 4.62 ± .47 | 5.54 ± .50* | 2.14 ± .35† | 1.26 ± .30† |
| Descend stairs | Time (s) | Prehab‡ | 12.44 ± 1.49 | 10.39 ± 1.26 | 13.21 ± 1.62 | 8.60 ± 1.12† |
| | | Control | 10.32 ± 1.41 | 10.45 ± 1.19 | 11.79 ± 1.53 | 8.06 ± 1.06 |
| | Pain | Prehab‡ | 4.64 ± .47 | 4.58 ± .51 | 1.83 ± .37 | 1.42 ± .37† |
| | | Control | 5.26 ± .44 | 5.65 ± .48 | 2.43 ± .35† | 1.45 ± .35† |
| Maximum extension strength of the surgical knee (torque/body wt.) | | Prehab | 53.84 ± 6.55 | 56.51 ± 6.16 | 43.15 ± 3.63 | 62.27 ± 5.00* |
| | | Control | 60.23 ± 6.31 | 54.02 ± 5.94 | 44.41 ± 3.50† | 60.74 ± 4.81 |
| Maximum extension strength of the nonsurgical knee (torque/body wt.) | | Prehab | 77.41 ± 8.85 | 79.50 ± 9.03 | 83.92 ± 9.48 | 90.26 ± 9.14* |
| | | Control | 81.87 ± 8.53 | 82.74 ± 8.70 | 95.45 ± 9.13* | 94.73 ± 8.81* |
| Strength asymmetry nonsurgical side minus surgical side | | Prehab | 23.57 ± 5.63 | 22.98 ± 6.14 | 40.77 ± 8.31 | 28.00 ± 6.93 |
| | | Control | 21.65 ± 5.43 | 28.72 ± .5.92 | 51.04 ± 8.00* | 33.98 ± 6.67* |

Shading indicates a significant within group change from baseline. Values are mean ± SEM.
*Indicates a significant increase within the study group from their baseline measure.
†Indicates a significant decrease within the study group from their baseline measure.
‡Note: One Prehab subject did not complete the descend stair assessment at baseline and therefore was not included in the analysis of this variable.

proving the other 3 functional tasks, along with a trend toward improving their quadriceps strength and decreasing their strength asymmetry compared with their T1 measures. The Control group at T2 reported greater levels of pain while performing the 6-minute walk and ascending stairs. Between T1 and T2 the Control group exhibited a nonsignificant trend toward declines in performing all of the functional tasks, decreases in strength in the surgical knee, and an increase in leg-strength asymmetry.

At T3 the prehabilitation group maintained a significant improvement in performing the sit-to-stand task with no other changes in performing functional tasks, pain, or strength compared with their T1 assessment. The Control group at T3 exhibited a significant decrease in their performance in the 6-minute walk and quadriceps strength in the surgical knee compared with their T1 measure. Also at T3 the Control group reported less knee pain while performing all of the functional tasks and a significant increase in their nonsurgical quadriceps strength compared with their T1 assessment. These changes in strength within both legs of the Control group resulted in a significant increase in strength asymmetry at T3 compared with T1.

At T4 the Prehab group exhibited significant improvements in performing all of the functional tasks except the 6-minute walk and reported significant decreases in all measures of knee pain. The Prehab group also improved the strength of their surgical and nonsurgical quadriceps compared with their T1 measures, which resulted in no change in their strength asymmetry over the duration of the trial. The Control group at T4 improved their performance of sit-to-stand and 6-minute walk only and reported decreases in all measures of knee pain when compared with T1. The Control group increased the quadriceps strength in their nonsurgical leg between T1 and T4, with no changes in strength in their surgical leg, which resulted in an increase in leg strength asymmetry.

## DISCUSSION

These findings generally sustain the 2 study hypotheses, appear to support the theory of prehabilitation, and indicate the efficacy of prehabilitation among TKA patients. Support for the theory of prehabilitation from the findings is best exemplified by the improvements in sit-to-stand within the study groups over the duration of the study. Figure 2, which graphically depicts the performance of the sit-to-stand functional task within the Prehab and Control groups over the duration of the study, is very similar to graphic depiction of the theory of prehabilitation (Figure 1) presented by Ditmyer et al in 2002 [19]. A possible explanation for the sit-to-stand task best supporting the hypotheses and theory of prehabili-

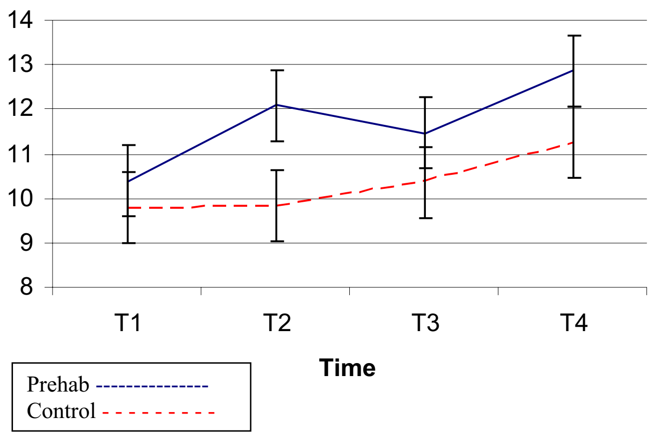


**Figure 2.** Sit-to-stand performance.

tation is that this functional task was very similar to the resistance training exercise of squats as a component of the prehabilitation intervention. This conclusion is supported by the principle of specificity of training [39], which indicates improvements in performance of functional tasks are dependent on the muscle group used and movement pattern performed. Because the squat exercise is very similar to the sit-to-stand functional task, improvements in this task would be expected earlier and to a greater extent than other functional tasks, which were dissimilar to the prehabilitation training (eg, walking).

Inconsistencies between components of the prehabilitation training and the procedures to measure functional ability and quadriceps strength may also account for the nonsignificant trends of the prehabilitation intervention to improve the other functional tasks and quadriceps strength observed in the Prehab but not the Control group before their TKA surgery. For example, the assessment of quadriceps strength used open chain movement, whereas the squat exercise involves a closed chain movement. A second explanation for the minimal effect of the prehabilitation intervention before the TKA surgery was the limited exposure the Prehab group had to the training. Subjects in the Prehab group participated in an average of 13 training sessions with a range of 4 to 23 sessions between T1 and T2 before their TKA. Previous studies [39] have indicated that the minimal duration of resistance training required to produce significant gains in strength is generally 6-8 weeks depending on initial fitness and intensity, frequency, and mode of training.

Finally, before TKA the Control group reported significant increases in knee pain while performing 2 of the functional tasks, whereas knee pain in the Prehab group did not change during this same duration. There are 2 explanations for these findings. First, The Prehab group may have experienced the pain-reducing effects of exercise reported by previous authors among knee OA patients who engaged in regular exercise [24,34]. Second, this benefit of the prehabilitation intervention may have been diluted by the common clinical practice of discontinuing a TKA patient's pain-relieving medication, primarily nonsteroidal antiinflammatory drugs, before surgery to minimize blood loss during and after surgery.

At 1 month after TKA surgery, the Prehab group appeared to maintain or improve their functional ability and quadriceps strength compared with beginning the trial with only a trend in decreasing their pain. The Control group significantly decreased their pain while exhibiting a significant decrease in their 6-minute walk distance and declines in quadriceps strength on the surgical side at T3 compared with their baseline values. Interestingly, in the Control group, quadriceps strength significantly improved in the nonsurgical leg, which in turn contributed to a significant increase in strength asymmetry. This finding may be attributable to the nonsurgical leg being favored by the Control group to a greater extent after the TKA thus resulting in increased strength. The consistent decreases in pain observed in the Control group and not in the Prehab group at T3 were unexpected but may be attributable to greater levels of activity or less pain medication consumption in the Prehab group.

Finally, at T4, 3 months after the TKA, the Prehab group demonstrated decreases in all measures of pain, improvements on 3 of the 4 functional tasks, and improvements in strength in both the surgical and nonsurgical quadriceps, with no significant change in strength asymmetry from their baseline measures. At T4, the Control group, similar to the Prehab group, significantly decreased all of their measures of pain and increased their nonsurgical quadriceps strength. The Control group at T4 did not improve their time to ascend or descend stairs or their quadriceps strength in their surgical leg during the course of the study. As well, at T4, the Control group continued to exhibit significant increases in strength asymmetry over their baseline measures. These findings may indicate the efficacy of the prehabilitation intervention to facilitate functional ability and gains in bilateral quadriceps strength up to 3 months following the TKA. The benefits of improved physical condition before a TKA positively impacting postoperative measures has been previously cited in observational studies [28,40,41]. The findings that the Control group exhibited greater strength asymmetry up to 3 months after their TKA indicates compared to their baseline measures may indicate they are at increased risk for other orthopedic problems due to biomechanical disruptions resulting from this asymmetry in strength [42].

## CONCLUSION

These findings demonstrate preliminary support for the efficacy of prehabilitation but also demonstrate the need for further study and should be tempered by a number of limitations. The sample self-selected to participate and was unblinded to group assignment and, therefore, may have had positive expectations regarding the benefits of prehabilitation. Because of this positive expectation of prehabilitation, control patients also may have clandestinely participated in other types of exercise or increased their physical activity before surgery contrary to the study protocol. Consumption of pain medication was not strictly measured in this study and may have affected the self-reports of pain. Future researchers studying similar clinical protocols may wish to quantify or control pain medication consumed by the sample 24 hours before all data collection. Further research is needed to standardize the number of prehabilitation sessions prior to surgery in order to enhance the positive impact of this intervention.

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