The Effect of a Prehabilitation Exercise Program on Quadriceps Strength for Patients Undergoing Total Knee Arthroplasty: A Randomized Controlled Pilot Study

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Objective: To examine the effect of a 6-week prehabilitation exercise training program on presurgical quadriceps strength for patients undergoing total knee arthroplasty (TKA).

Design: Two-arm, parallel, randomized, controlled pilot trial.

Setting: Private exercise space in a research facility.

Participants: Twenty-two patients scheduled for primary TKA.

Methods: Participants completed a series of baseline questionnaires (Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC], Short Form 36, and Arthritis Self-efficacy Scale) and functional testing (isometric quadriceps strength assessment, flat-surface walk test, and stair ascent-descent test). The participants were randomized to a lower-body strength training program or to a nonspecific upper-body strength training program. The participants exercised 3 times per week for 6 weeks before TKA. Postintervention assessment occurred immediately before TKA, with follow-up assessments at 6 and 12 weeks after surgery.

Outcomes: The primary outcome was isometric quadriceps strength. Secondary outcomes were mobility, pain, self-reported function, health-related quality of life, and arthritis self-efficacy.

Results: There was no significant treatment condition–by-time effect on quadriceps strength, but the effect size was large ($F_{3,18} = 0.89$, $P = .47$, $\eta^2 = 0.13$). Similar findings were shown for walking speed ($F_{3,18} = 1.47$, $P = .26$, $\eta^2 = 0.20$). There was a significant treatment-by-time effect for the Short Form 36 mental component score ($F_{3,18} = 0.41$, $P = .02$, $\eta^2 = 0.41$), with differences emerging before surgery but not at either postoperative assessment. For all other secondary outcome measures, the treatment-by-time effect was nonsignificant and small.

Conclusion: The intervention elicited clinically meaningful increases in quadriceps strength, walking speed, and mental health immediately before TKA. It did not impart lasting benefits to patients in the 12 weeks after surgery. Analysis of the results suggests that quadriceps strength may not drive functional improvements after surgery. These findings need to be replicated in larger trials before clinical recommendations are made about including strength training prehabilitation in everyday practice.

PM R 2012;4:647-656

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Peer reviewers and all others who control content have no relevant financial relationships to disclose.

Disclosure Key can be found on the Table of Contents and at www.pmrjournal.org

INTRODUCTION

Osteoarthritis (OA) is the most common disabling musculoskeletal disorder worldwide, and its prevalence is rising in response to our upward-shifting population demographics [1]. Reflecting this trend, the number of total knee arthroplasties (TKA) performed each year is also increasing, with more than 441,000 reported in the United States in 2004 alone [2]. Although the surgery is generally effective in terms of pain reduction and correcting joint alignment, patients do not always achieve a return to full function and may be left with limitations in mobility and other activities of daily living [3]. In fact, results of studies have shown that strength deficits and functional impairments may persist for up to 2 years after TKA [4,5]. Preoperative function is the greatest overall predictor of postoperative function

PM&R
1934-1482/12/$36.00
Printed in U.S.A.

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Vol. 4, 647-656, September 2012
http://dx.doi.org/10.1016/j.pmrj.2012.04.012

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for those undergoing TKA [3]. Therefore, researchers have begun to examine the potential role of prehabilitation, or presurgical intervention, as a means of improving patient outcomes after arthroplasty [6-8]. Because quadriceps strength is one of the largest contributing factors to function for those with knee OA, strength training, focused on the knee extensors, has been a common intervention. However, evidence to support its benefit as a prehabilitation modality is inconclusive. Although some studies have reported improved postoperative strength [9-11], mobility [12], and self-reported function [12] for patients engaging in various types of strengthening interventions, other studies have found no effect [13-16]. Although the intervention length was similar in most cases (4-6 weeks), differences in program content or outcome measurements could account for these equivocal findings.

A number of these programs, for instance, have been multimodal in nature, combining different types of exercise (eg, resistance and flexibility training) or exercise along with other interventions (eg, education, nutritional counseling) [10,16-19]. These combinations may have diluted the impact of one particularly effective component of the intervention or the individual components may not have been prescribed at the dose necessary to convey benefit. Multimodal interventions also make it difficult to determine which part of the program is responsible for any benefits that the patients did experience. Examination of strength training as a stand-alone intervention, therefore, is necessary to fully understand its impact on TKA outcomes.

Moreover, multimodal interventions are challenging from a public health perspective because their complexity necessitates a great deal of direction and supervision by trained program administrators. Paring an intervention down to its effective components would likely increase the uptake and long-term sustainability of a prehabilitation program by minimizing the resources required to maintain it. Developing simple interventions with a limited need for specialized equipment or expertise could also allow for community- or home-based implementation, which would make prehabilitation more accessible to the target population.

In addition, previous studies focused primarily on physiological and clinical outcomes after TKA. With increasing emphasis on patient quality of life as a measure of treatment success [20], it is important to consider what impact prehabilitation may have on subjective assessments of physical and mental well-being. It also is necessary to account for other psychological factors that may ultimately affect functional outcomes after surgery, for example, self-efficacy. Defined as the perception of one's ability to perform a task successfully, self-efficacy directs individual behavior, effort, and persistence in the face of obstacles [21]. Although it is generally considered to be domain specific, a partial transfer of increased efficacy expectations between similar situations has been reported [21,22].

For those with OA, a greater sense of efficacy to exert control over how one's symptoms affect daily living activities has been shown to predict functional disability, regardless of pain level or disease duration [23,24]. In fact, self-efficacy has been reported to account for between 7% and 21% of variance in function for patients with OA [25,26]. For those undergoing TKA, self-efficacy has been linked to decreased self-reported pain, greater self-reported function, and improved quality of life in both pre- and postoperative assessments [27-31]. Specifically, Engel et al [27] found that preoperative self-efficacy and expectancies explained, on average, 10% of the postoperative variance in self-reported pain, function, and health-related quality of life for patients with TKA. Similarly, van den Akker-Scheek et al [28] reported that preoperative self-efficacy significantly predicted walking speed 6 months after knee or hip arthroplasty ($R^2 =$ 0.47). Postoperative self-efficacy has been shown to be a significant predictor of long-term physical and mental functioning after TKA.28 Although self-efficacy has not been examined in the context of prehabilitation, it is amenable to change and, therefore, is potentially modifiable by a targeted intervention.

The purpose of this pilot study was to examine the effect of a simple and easy-to-implement prehabilitation exercise training program on quadriceps strength for patients undergoing TKA. It also represents an initial investigation of self-efficacy as an outcome of the prehabilitation intervention. The primary outcome was postoperative quadriceps strength, and the secondary outcomes were mobility, pain, self-reported function, health-related quality of life, and arthritis self-efficacy. It was hypothesized that patients in the lower body strength-training condition would exhibit greater quadriceps strength than those in the control condition at the end of intervention and at 6- and 12-week follow-ups after surgery. It also was expected that these patients would report greater mobility and less pain as well as report better function, quality of life, and arthritis self-efficacy at these time points compared with their control counterparts.

METHODS

Participants

Participants were recruited from April to December 2010 using a convenience sampling strategy from the outpatient clinic of a single orthopedic surgeon who specializes in joint replacement. All participants had a primary diagnosis of knee OA and were scheduled for unilateral TKA with this same single orthopedic surgeon at least 6 weeks after their date of recruitment. Potentially eligible patients were first informed of the study by the surgeon during their initial consultation. Patients were eligible if they (1) had a primary diagnosis of knee OA, (2) were ambulatory with or without a walking aide, and (3) exhibited unilateral or bilateral OA symptoms.

Patients were excluded if they (1) had scheduled additional, unrelated surgery within 3 months of their TKA, (2) had undergone surgery in the 3 months before recruitment, (3) had contraindications for exercise, or (4) were undergoing a revision surgery. All of the participants provided written informed consent as per the institutional health research ethics board.

Design

A standard 2-arm, parallel, randomized, controlled pilot trial was conducted.

Intervention

Participants in the intervention group were prescribed a training program that consisted of a 10-minute aerobic warm-up (participant's choice of using a treadmill, cycling ergometer, rowing ergometer, or recumbent stepper), followed by a circuit of bilateral lower body exercises (standing calf raise, seated leg press, leg curl, knee extension). Participants performed 2 sets of 8 repetitions of each exercise. Calf raises were performed with body weight only, although the remaining exercises began at 60% of their one repetition maximum and increasing gradually by increments of 1-2 kg per week, as tolerated, over the course of the 6-week intervention.

Patients randomized to the placebo control group were prescribed a training program that consisted of the same 10-minute aerobic warm-up as the intervention group, followed by a circuit of bilateral upper body exercises (seated latissimus dorsi [lat] pull, chest press, elbow flexion, elbow extension). Participants performed 2 sets of 8 repetitions of each exercise, beginning at 60% of their one repetition maximum and increasing gradually by increments of 1-2 kg per week, as tolerated, over the course of the 6-week intervention. The participants in both conditions were prescribed 3 exercise sessions per week for 6 weeks, with each session approximately 30 minutes in length. Exercises were performed on HUR fitness equipment (Ab Hur Oy, Kokkola, Finland), and all participants had one-on-one supervision by a trained kinesiologist during each of their sessions to ensure proper exercise technique and to provide equal individualized contact time between conditions. Identical treatment contact time was provided to both groups to distinguish the specific effect of exercise from the nonspecific impact of receiving more treatment.

Physiological states can inform efficacy beliefs by influencing individuals' cognitive appraisal of the source, intensity, and context of somatic input, thereby allowing those individuals to derive subjective feedback about their ability to perform a given behavior [21]. By focusing on improving participants' perceptions of their physiological state through constant feedback about their performance, the present in-tervention was designed to increase self-confidence in their ability to perform either lower body (intervention group) or upper body (control group) strength-dependent daily living activities. The placebo condition controlled for the effects of mastery experience derived from exercising, thereby ensuring that changes in self-efficacy could be attributed to physiological state interpretation. The participants completed their training program within 3 days of surgery. One surgeon performed all TKAs, and all of the participants received standard postoperative care from a single physiotherapist through the hospital-based program.

Primary Outcome Measure: Isometric Strength Assessment

After a 5-minute warm-up of walking on a treadmill at a self-selected comfortable pace, the participants were seated in the HUR leg extension machine, and their thighs were strapped down by using inelastic straps with Velcro closures (Velcro USA Inc, Manchester, NH) to ensure quadriceps isolation. The lever arm of the machine was positioned at 75°, and the pad was placed just above the foot of the surgical limb [4]. After 2 familiarization bouts at 50% and 75% of maximum effort, respectively, the participants were given 5 minutes to rest before 2 test trials were performed. The participants were instructed to contract their quadriceps as forcefully as possible, pushing their leg against the pad of the lever arm. A force meter attached to the lever arm recorded the force output in Newtons (N), and the trial was stopped at the participants' peak force output. The second trial was performed after a rest period of 3 minutes, and the highest force output from the 2 trials was used in the analysis. The participants received verbal encouragement during both trials.

Secondary Outcome Measures

Flat Surface Walking Test. The participants were asked to walk a distance of 50 feet, from a standing start, in a straight, quiet corridor. Those who used a walking aide for regular ambulation were permitted to use it during this test. The participants were timed by using 2 digital stopwatches (accurate to 1/100th of a second), and the average of the 2 times was recorded for the trial. Each participant performed 2 trials, separated by 3 minutes. The faster of the 2 average times was used in the analysis.

Stair Ascent-Descent. This test consisted of a stair climb, followed by a stair descent. The participants began from a standing start and were instructed to climb one flight (13 steps) of standard stairs by using the railing for balance if necessary. At the top of the stairs, they immediately reversed direction and descended the same staircase. Again, the test was timed by using 2 digital stopwatches (accurate to 1/100th of a second), and the average of the 2 times was

recorded for the trial. If the participants thought that they could perform a second trial safely, they were encouraged to do so. The fastest (or only) averaged time from the trials was used in the analysis.

Western Ontario and McMaster Universities Osteoarthritis Index.
The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) is a 24-item, self-administered questionnaire divided into subscales for pain (5 items), joint stiffness (2 items), and physical function (17 items) [32]. It is rated on a 5-point Likert scale (0-4), with lower scores indicating lower symptom or disability levels. The instrument is scored by summating each subscale or by computing a global score. The Cronbach α for the subscales range from 0.86 to 0.97, and test-retest reliability of the global score ranges from 0.77 to 0.83 [33,34].

Medical Outcomes Study Short Form 36.
The Short Form 36 (SF-36) is a commonly used measure of general health and related quality of life [35]. It consists of 8 subscales (bodily pain, physical function, general health, mental health, social functioning, vitality, role-physical, and role-emotional), with the Cronbach α coefficients that range from 0.78 to 0.93 [35]. Each of the subscales is transformed into a 0-100 scale for scoring. Two summary scores can be derived from the questionnaire: the physical component summary (PCS), and the mental component summary (MCS).

Arthritis Self-efficacy Scale.
The Arthritis Self-efficacy Scale is a measure of perceived efficacy to cope with arthritis [36]. It consists of 20 items scored on a scale of 0-10, in which higher scores indicate greater self-efficacy. The scale has 3 subscales to measure pain (5 items), physical function (9 items), and other symptoms (6 items); these subscales have demonstrated good reliability, with the Cronbach α coefficients of 0.76, 0.89, and 0.87, respectively, and test-retest reliabilities of 0.87, 0.85 and 0.90, respectively [36]. A total score for the questionnaire is obtained by summating the 3 subscale scores to a maximum score of 200.

Procedure

Participant flow through the study is illustrated in Figure 1. Baseline testing occurred 6 weeks (±3 days) before the participant's scheduled arthroplasty. All of the participants were asked to complete the questionnaire package, which consisted of the following: (1) demographic questionnaire, (2) WOMAC [32], (3) Arthritis Self-efficacy Scale [36], and (4) Medical Outcomes Study SF-36 [35]. After completing the questionnaires, the participants performed the timed 50-foot flat surface walking test, the timed single-flight stair ascent and descent, and the isometric quadriceps extension assessment (by using a HUR 3530 extension-curl machine). After the baseline testing, the participants were randomized to either the lower body strength training intervention condition or the placebo control condition. The participants

were block randomized by gender by using sealed opaque envelopes. The participants again completed the questionnaire battery and physical testing at the end of the 6-week intervention, as well as at 6 and 12 weeks after their surgery. The conduct of the trial followed the recommendations of the Consolidated Standards for Reporting of Trials [37] and the ethical principles of research outlined in the Declaration of Helsinki [38] and the World Health Organization's Handbook for Good Clinical Research Practice [39].

Analysis

The data were analyzed by using SPSS for Windows (version 18; SPSS Inc, Chicago, IL). All results were based on an intent-to-treat analysis strategy. A series of repeated-measures analysis of variance were conducted to investigate the effect of prehabilitation on postoperative outcomes (quadriceps strength, walking, and stair ascent-descent tests; WOMAC scores; the SF-36 PCS and MCS; and arthritis self-efficacy). The level of significance was accepted at $P <$ .05 for all statistical tests [40]. In accordance with Cohen [41], 0.01 constitutes a small effect size, 0.06 constitutes a moderate effect size, and 0.14 constitutes a large effect size (η^2). Because this was a pilot study, no power calculation was conducted to determine an appropriate sample size.

RESULTS

A total of 22 participants were recruited and randomized. Their baseline characteristics are summarized in Table 1. There were no significant differences between the 2 groups in terms of participant characteristics or baseline scores on any of the outcome measures (Tables 1 and 2). Training session attendance in the control group was 93% (201/216 possible sessions) and in the prehabilitation group 98% (177/180 possible sessions). Training data are summarized in Table 3. All of the participants increased their training loads for each exercise over the course of the intervention.

Quadriceps Strength

There was a significant time effect on the primary outcome of quadriceps strength ($F_{3,18} = 5.56$, $P <$ .01, $\eta^2 = 0.48$), but there was no significant time-by treatment interaction ($F_{3,18} = 0.89$, $P =$ .47, $\eta^2 = 0.13$) (Figure 2).

Mobility

There was a significant time effect on the 50-foot flat surface walking test ($F_{3,18} = 6.79$, $P =$ .03, $\eta^2 = 0.53$), but there was no significant time-by-treatment interaction ($F_{3,18} = 1.47$, $P =$ .26, $\eta^2 = 0.20$). Seventeen participants (8 intervention, 9 control) performed 2 trials of the stair ascent-descent test, whereas 5 (2 intervention, 3 control) performed only one. There was no significant effect of time ($F_{3,18} = 2.64$, $P =$ .79,
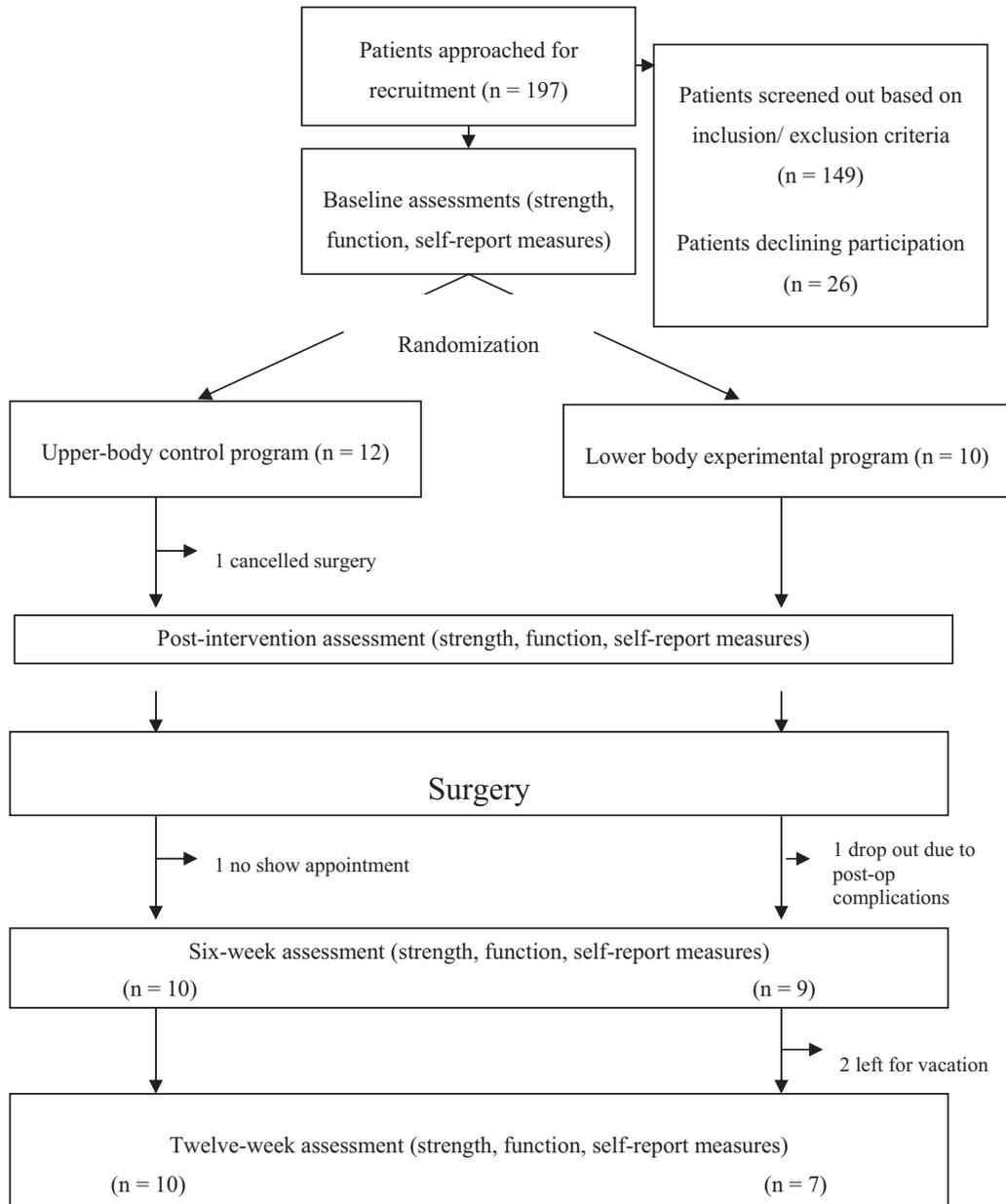
Figure 1. Participant flow through the trial.

Table 1. *Randomized participant characteristics*

	Control Group (n = 12)	Intervention Group (n = 10)
% Women	66.67	50
Mean (SD) age, y	60.58 ± 8.05	63.5 ± 4.93
Mean (SD) BMI, kg/m^2	33.78 ± 7.05	35.03 ± 6.13
No. patients who used a walking aid	3	2
No. patients with bilateral osteoarthritis	9	10

SD = standard deviation; BMI = body mass index.

$\eta^2 = 0.32$), nor was there a time-by-treatment interaction ($F_{3,18} = 0.04$, $P = .99$ $\eta^2 = 0.01$) for the stair ascent-descent test.

Pain and Self-reported Function

Based on scores from the WOMAC, there was a significant time effect for pain ($F_{3,18} = 20.32$, $P < .01$, $\eta^2 = 0.77$) and self-reported function ($F_{3,18} = 22.78$, $P < .01$, $\eta^2 = 0.79$), but no time-by-treatment interaction for either pain ($F_{3,18} = 0.35$, $P = 0.54$, $\eta^2 = 0.05$) or function ($F_{3,18} = 0.52$, $P = .67$, $\eta^2 = 0.08$).

Table 2. *Means (SD) of outcome measures between groups across assessment time points*

	Baseline	Postintervention	6 Wk Postop	12 Wk Postop
Quadriceps strength, NM/kg				
Control	0.84 ± 0.52	0.81 ± 0.52	0.57 ± 0.29	0.74 ± 0.35
Prehab	0.96 ± 0.58	1.03 ± 0.57	0.60 ± 0.39	0.77 ± 0.56
50-foot walk, s				
Control	14.21 ± 5.36	12.63 ± 3.51	13.11 ± 3.30	11.82 ± 2.97
Prehab	16.88 ± 16.14	11.38 ± 5.95	14.23 ± 7.55	11.80 ± 5.66
Stair test, s				
Control	33.31 ± 27.42	23.28 ± 11.70	26.72 ± 12.05	22.18 ± 10.98
Prehab	34.53 ± 29.51	26.86 ± 24.89	30.53 ± 24.85	26.99 ± 26.73
WOMAC pain				
Control	11.92 ± 3.58	9.00 ± 4.41	4.92 ± 4.50	3.58 ± 4.40
Prehab	10.80 ± 2.20	8.70 ± 3.77	5.60 ± 2.72	4.40 ± 3.20
WOMAC function				
Control	40.25 ± 4.99	30.50 ± 13.68	19.17 ± 15.01	14.33 ± 15.42
Prehab	33.70 ± 11.80	28.50 ± 12.57	18.10 ± 11.85	13.10 ± 11.56
SF-36 PCS				
Control	24.24 ± 4.52	25.61 ± 5.77	29.80 ± 6.71	34.83 ± 9.78
Prehab	26.85 ± 7.01	29.66 ± 7.99	31.79 ± 8.25	41.25 ± 10.06
SF-36 PCS				
Control	46.72 ± 16.49	42.28 ± 15.28	46.68 ± 15.97	51.46 ± 16.37
Prehab	52.14 ± 11.75	52.76 ± 7.79	49.35 ± 10.47	48.02 ± 17.45
Self-efficacy				
Control	139.25 ± 33.91	141.08 ± 33.84	158.08 ± 25.54	166.58 ± 25.99
Prehab	139.90 ± 28.91	141.70 ± 26.31	159.20 ± 31.82	178.10 ± 19.60

SD = standard deviation; postop = postoperative; prehab = prehabilitation; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index; SF-36 = Short Form 36; PCS = physical component summary; MCS = mental component summary.

Health-related Quality of Life

There was a significant time effect on the PCS of the SF-36 ($F_{3,18} = 9.94$, $P < .01$, $\eta^2 = 0.62$), but there was no time × treatment interaction ($F_{3,18} = 0.10$, $P = .58$, $\eta^2 = 0.10$). The MCS, however, showed no time effect ($F_{3,18} = 0.07$, $P = .07$, $\eta^2 = 0.07$), but there was a significant time × group interaction ($F_{3,18} = 0.41$, $P = .02$, $\eta^2 = 0.41$) (Figure 3). To explore this significant interaction further, an analysis of covariance was conducted to examine effects at each time point while controlling for baseline values. At the postintervention assessment, there was a trend effect in favor of prehabilitation treatment ($F_{1,19} = 3.55$, $P = .08$, $\eta^2 = 0.16$). No differences between groups were found at the 6-week postoperative assessment ($F_{1,19} = 0.02$, $P = .89$, $\eta^2 = 0.001$) or at the 12-week postoperative assessment ($F_{1,19} = 1.06$, $P = .32$, $\eta^2 = 0.05$).

Arthritis Self-efficacy

There was a significant time effect on self-efficacy ($F_{3,18} = 9.09$, $P = .01$, $\eta^2 = 0.60$), but there was no significant time × treatment interaction ($F_{3,18} = 0.51$, $P = .08$, $\eta^2 = 0.08$).

DISCUSSION

Quadriceps Strength

The significant time effect associated with quadriceps strength is consistent with expectations after TKA. Strength

Table 3. *Mean (SD) change and percentage increase (range) in maximum training loads (kg) from baseline to the end of the training period*

	Control Group	Intervention Group
Lat pull	+4.18 ± 2.70; +118% (17%-450%)	—
Chest press	+2.82 ± 1.33; +51% (0%-100%)	—
Elbow flexion	+2.64 ± 1.91; +71% (0%-200%)	—
Elbow extension	+2.82 ± 1.33; +51% (13%-83%)	—
Calf raise	—	N/A
Leg press	—	+3.60 ± 3.41; +33% (17%-67%)
Knee extension	—	+4.30 ± 2.50; +86% (0%-167%)
Leg curl	—	+8.20 ± 4.80; +49% (0%-113%)

Lat = seated latissimus dorsi; SD = standard deviation; N/A = not available.
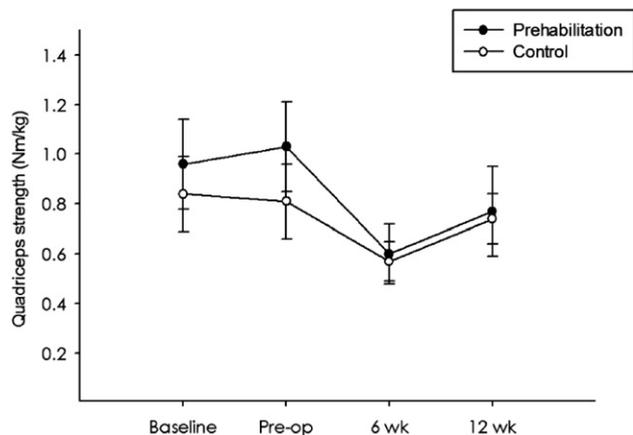
Figure 2. Quadriceps strength between groups (mean (standard deviation)).

reduction of up to 60% has been found immediately after TKA, which has largely been attributed to neuromuscular activation failure [4,42-45]. Patients in the experimental group showed no advantage over the control participants after surgery, which indicates that the simple strengthening exercises in this intervention did not train neuromuscular activation to the extent necessary to overcome this deficit. A targeted training program or a strengthening regimen of greater length or intensity may have yielded greater postoperative benefits.

Yet, despite a nonsignificant interaction between time and treatment condition, the large effect size of 0.13 suggests that the intervention did improve preoperative strength to a clinically meaningful degree. The magnitude of the strength gains in the intervention group was similar to the 20% preoperative gain found by Rooks et al [16] in a study that examined a comprehensive, 6-week strengthening program. Thus, not only is it possible for patients with severe knee OA to achieve strength gains within 6 weeks, but this improvement can occur during a time that is typically characterized by worsening symptoms [46]. Although this evidence supports the use of strength training as an intervention modality, the benefits were short lived, which indicates that it may not be adequate as a stand-alone prehabilitation intervention.

In contrast to the findings of Topp et al [10], who demonstrated a significant increase in strength at 12 weeks after surgery compared with baseline levels for patients with TKA who were undergoing strength training prehabilitation, neither group demonstrated a return to preoperative strength values by the 12-week follow-up. Yet, this did not seem to have an impact on walking speed, stair climb, WOMAC scores, or SF-36 scores. Quadriceps strengthening, therefore, may not be necessary to achieve functional improvements in the first 3 months after TKA.

Secondary Outcomes

The significant main effect of time on the flat-surface walking test was also expected. Although the decrease in performance after surgery and subsequent rebound, regardless of group, reflects the effect of the operation itself, it was surprising that both groups improved during the preoperative period. This may simply be the result of patients increasing their level of physical activity through participation in the study; or warming up before exercising, which most participants did by walking on a treadmill, may have been enough to improve their walking speed.

The very large effect size associated with the time × group interaction ($\eta^2 = 0.20$) indicates that the magnitude of change in walking speed for the prehabilitation group may be greater than for the control group before surgery (ie, postintervention period). It appears that the differences between groups disappeared by the 6-week follow-up however, which suggests that any gains made before surgery have only short-term effects.

There was no significant time or interaction effect associated with the stair ascent-descent test, although the effect size of time was quite large ($\eta^2 = 0.32$). Navigating stairs requires proprioception and balance, both of which are impaired in individuals with OA [47]. If the participants in both groups had similar deficits, this may account for the similarities at all time points, irrespective of strength differences in the preoperative period. TKA provides a great deal of pain relief for most patients [48], so it is not surprising that both groups demonstrated a steady downward trend. Other researchers have found similar decreases in pain from presurgical levels through rehabilitation. Jaggers et al [12] reported significant decreases in WOMAC pain scores in both the strength training and standard care patients in their case-control study.
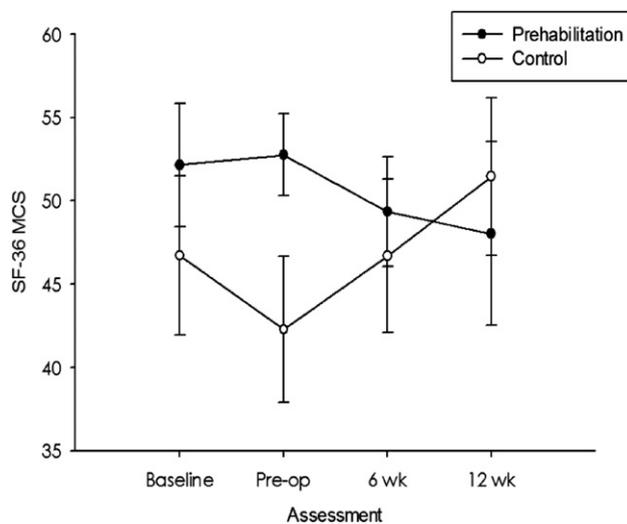
Figure 3. Short Form 36 (SF-36) mental component summary (MCS) scores between groups (mean (standard deviation)).

Rooks et al [16] also showed comparable pain reductions in their exercise and control groups from the preoperative time point through 8- and 26-week postoperative follow-ups.

The reason that the control group's pain improved in the preoperative period in the present study, however, is not as clear. Exercise has been found to reduce pain for OA patients [49], and perhaps this effect is not dependent upon the type of exercise. It could be that simply engaging in some form of physical activity was enough to trigger this response, which indicates that any type of exercise-based intervention would provide this benefit.

Subjectively, the TKA procedure imparted similar functional improvements to participants in both groups. Interestingly, the nearly identical trajectory of self-reported function in both groups does not reflect the differences in walking speed or quadriceps strength between them. Although the improvements at the postoperative assessments were expected, the magnitude of the preoperative change in the control group was not. Indeed, Jaggers et al [12] reported worsening self-reported function in their control patients, and Rooks et al [16] reported no change in their control group. The findings from the present study suggest that perceived functional ability might have an inverse relationship to pain, which may be a stronger association than that between perceived and objectively measured function in this patient group.

The results concerning the physical component of health-related quality of life once again follow the expected pattern. The mental component scores, however, demonstrate a time-by-group interaction. It appears that participants in the control condition experienced worsening psychological health leading up to surgery, then rapidly improved alongside reductions in OA symptoms after TKA. Those in the prehabilitation condition had a small increase in psychological health with the intervention but experienced a large setback after surgery, which may be because prehabilitation patients tend to have greater outcome expectations associated with TKA, and, when these are not met, react negatively, whereas patients in the control group may have their expectations met or exceeded and therefore react more positively. Additional research is recommended to test this hypothesis.

The improvements in arthritis self-efficacy in this study were clearly tied to reductions in symptoms. Although both groups showed a small improvement before surgery, which was likely due to pain reduction, the largest gains occurred after surgery, which is consistent with the self-efficacy theory, which states that personal experiences and changes in physiological and affective states are sources of efficacy beliefs [21].

Study Limitations

A major limitation of this study is its small sample size. Although a large effect size in the expected direction was found in many of the relationships investigated, there was insufficient power to detect statistically significant differences between the groups. It, therefore, is recommended that the results of the present pilot study be used to power larger trials.

Selection bias may have influenced the results, although nonparticipation was largely due to rural-dwelling patients with TKA not having transportation to the research facility for thrice-weekly training sessions. Although this may speak to the feasibility of implementing this type of program in similar communities, it is not likely to have systematically affected the outcomes. The number of dropouts in both groups was equal, and the reason for discontinuation appeared to be unrelated to the intervention in most cases (ie, scheduled vacations, cancelled surgery) (Figure 1). Although this loss to follow-up contributed to the low power of the study, it is not likely to have affected the direction of the observed relationships between the intervention and outcomes.

Another limitation of this study is the timing of the follow-up assessments. It is possible that the effects of the prehabilitation intervention were more pronounced earlier after surgery but that they had begun to wash out by the 6-week measurement time point. It would also be useful to have a longer follow-up period to identify when strength levels returned, or indeed surpassed, baseline levels, which would allow for a much more global understanding of the effects of prehabilitation for patients with TKA.

It is also possible that, because the lower body strengthening program included open kinetic chain exercises, pain inhibition may have occurred and thus limited some of the training effect. Although the effect of training was in the expected direction, based on the mean gain in training volume, the magnitude of the increase may have been larger if closed chain exercises were prescribed. However, the magnitude of the gains in the knee extension training loads were greater than both the lat pull and chest press exercises, which would suggest that pain did not particularly inhibit the ability of the subjects to perform contractions of adequate intensity to yield a training response. Another limitation is that quadriceps strength was assessed isometrically, whereas the training program was based on isotonic exercises, which may have diluted the measured treatment effect, although mean increases in training weight of 33% (leg press) and 86% (knee extension) suggest meaningful strength improvements. Finally, the results of this study may not be generalizable to other surgical populations. When considering the relationship between muscle strength and disability for those with knee OA in particular, it is possible that those with OA of other joints may not respond as favorably to strength training.

Future Directions

Although this intervention positively influenced strength, function, and psychological health before surgery, the effect of the TKA itself appeared to override these benefits to the point that they washed out in the follow-up period. It is

possible that the dose or length of the present intervention was insufficient to convey lasting benefits to patients, so future studies might aim to manipulate the intervention content to increase the magnitude of the preoperative effect.

This study also showed a direct effect of lower limb strength training prehabilitation on mental health. This relationship needs to be further investigated to determine which aspect of the intervention (strength training or simply contact with the experimenters) was responsible for this effect and how it may affect long-term psychological functioning. Because a variety of exercise types have been shown to have a positive impact on health-related quality of life, future studies should include a true control group alongside a number of different exercise protocols to determine which specific activities elicit the observed effect. In addition, the differential relationship between TKA and MCS scores for prehabilitation versus control patients must be examined to ensure that boosting mental health before surgery does not have negative consequences in terms of physical recovery. The feasibility of conducting this type of intervention should also be explored in future studies. When considering that the demands of thrice-weekly exercise sessions in a research facility resulted in some difficulty recruiting for the present study, examining uptake in home-based or community-based settings would help to determine the potential long-term viability of prehabilitation programs.

CONCLUSIONS

The strength training prehabilitation intervention examined in this pilot study elicited clinically meaningful increases in quadriceps strength, walking speed, and mental health before TKA. It did not, however, impart lasting benefits to patients above and beyond what was conveyed by the surgery itself. The large nonsignificant effect sizes associated with the time-by-group interactions for many of the outcomes examined are encouraging and suggest that the study was underpowered due to its small sample size. Furthermore, analysis of the results suggests that quadriceps strength may not drive functional improvements after surgery. It is recommended that these findings be replicated in larger trials before clinical recommendations are made about including strength training prehabilitation in everyday practice.

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CME Question

Which of the following factors were found to be clinically improved by prehabilitation before total knee arthroplasty?

a. preoperative quadriceps strength
b. postoperative stair climbing
c. pre- and postoperative SF-36 MCS
d. postoperative medication use

Answer online at me.aapmr.org