Preoperative Quadriceps Strength Predicts Functional Ability One Year After Total Knee Arthroplasty

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ABSTRACT. ***Objective.*** Quadriceps weakness is common after total knee arthroplasty (TKA) as is longterm disability. We hypothesized that preoperative quadriceps strength would be the best predictor of postoperative functional ability when compared to preoperative pain or knee range of motion (ROM).

Methods. Forty subjects (mean age 63 ± 8 yrs, body mass index 29.4 kg/m^2 ± 4.2) were tested 2 weeks before and one year after TKA. Quadriceps strength was measured isometrically, pain was quantified using the Medical Outcome Study Short-Form 36 (SF-36) bodily pain subset, and knee flexion range of motion (ROM) was assessed by goniometer. Performance based functional assessment included the Timed Up and Go test (TUG) and a timed Stair Climbing Test (SCT). The Knee Outcome Survey (KOS) and the SF-36 questionnaires were used to quantify perceived function. The ability of preoperative factors to predict postoperative outcomes was analyzed using hierarchical regression. Differences in means before and one year after surgery were analyzed using paired t tests.

Results. Significant improvements were found in all functional measures assessed ($p < 0.001$). Preoperative quadriceps strength accounted for the bulk of the variance in the one-year SCT and the TUG ($p < 0.001$), but did not achieve significance in predicting one-year questionnaire scores ($p > 0.05$). Neither preoperative pain nor knee ROM were significant predictors of any functional measure ($p > 0.05$).

Conclusion. Preoperative quadriceps strength plays a dominant role in predicting one-year SCT and TUG functional measures, but it is not a good predictor of score on self-report questionnaires. Preoperative bodily pain and knee flexion ROM are poor predictors of all functional outcome measures. (J Rheumatol 2005;32:1533-9)

Key Indexing Terms:
OSTEOARTHRITIS — TOTAL KNEE ARTHROPLASTY — STRENGTH
KNEE — FUNCTIONAL ABILITY — OUTCOMES

Total knee arthroplasty (TKA) is a very common procedure, principally implemented for the treatment of knee osteoarthritis (OA)[1,2]. The prevalence of TKA in the US is predicted to continue rising with numbers approaching half a million surgeries annually by the year 2030[3]. Advancements in the durability of the endoprostheses have made it possible for younger patients with severe disease to undergo TKA[4]. The National Hospital Discharge Survey 1996-99 reported that individuals between 45 and 64 years old represent the fastest growing age group to undergo TKA[3]. An increasing incidence in TKA and a rise in utilization by a relatively younger patient population have prompted considerable interest in determining factors that influence postoperative outcome.

Determination of functional capacity can be performed through the use of self-assessment questionnaires or through performance based functional tests. Recent evidence has shown that preoperative self-report questionnaire scores consistently predict postoperative questionnaire scores[1,5-8]. While those patients who score lower on a questionnaire prior to surgery make the most improvements following TKA, they ultimately do not reach the same functional level as those with higher scores prior to surgery[8]. Results of functional assessment in individuals with knee OA show only modest correlations between the questionnaires and performance[9,10]. The majority of patients who undergo TKA attain good to excellent ratings on self-assessment questionnaires[11]. Questionnaire scores improve considerably in almost all patients, yet performance based functional tests do not show as much improvement. Walking performance remains roughly 20% lower in individuals with TKA com-

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pared to age matched cohorts[12,13]. More physically demanding tasks such as stair climbing have even greater disparity from well-elderly populations with deficits of roughly 50%[12]. The majority of patients continue to report at least moderate difficulty with heavy domestic duties (e.g., vacuuming) at 6 months after surgery[5]. Preoperative self-report questionnaires, therefore, may not predict longterm functional performance as well as other preoperative clinical measures.

Muscle weakness affects functional performance in older adults[14-18]. Loss of muscle mass and overall strength with aging (sarcopenia) have been well documented; however, weakness of the quadriceps femoris muscle has specific implications for knee OA. Quadriceps weakness has been implicated in the development[19] and progression of joint degeneration[20], and has been reported to be the strongest single predictor of functional limitations in patients with knee OA[21]. Quadriceps strength declines precipitously after TKA, with reports of strength loss of 60% in the acute perioperative period[22]. Recovery of quadriceps strength to normal levels is rare, and the majority of evidence finds substantial weakness in longterm assessments[23-25].

The potential for preoperative functional questionnaire scores to predict postoperative questionnaire scores may be helpful in operative planning, but does not offer specific direction for preoperative interventions aimed at improving surgical outcomes. Pain and range of motion (ROM) are also likely not amenable to non-operative intervention at this stage of disease. In contrast, measures of quadriceps weakness may represent a specific modifiable preoperative factor that could influence surgical outcomes.

We assessed the predictive value of preoperative quadriceps strength on functional performance one year after TKA for knee OA. We hypothesized that impairment in preoperative quadriceps strength would be the best predictor of postoperative functional ability when compared to preoperative pain or knee ROM.

MATERIALS AND METHODS

Subjects. Forty subjects (25 men, 15 women) who were scheduled to undergo unilateral TKA for OA were subjects for this study. Subjects were recruited on a consecutive basis from a group of local orthopedic surgeons who performed tricompartmental, cemented TKA with a medial parapatellar surgical approach. Potential subjects were excluded from the study if they had musculoskeletal involvement other than impending unilateral TKA that was limiting their function or if they were diagnosed with uncontrolled blood pressure, diabetes mellitus, neoplasms, neurological disorders, or a body mass index (BMI; weight in kg/m^2 height) > 40 (morbidly obese). The uninvolved knee was not screened for radiographic arthritic changes. If patients had average knee pain > 4/10 on a verbal analog scale or if they planned to have surgery on the uninvolved knee within a year, they were excluded. Subjects' average age was 63 ± 8 years (range 50–82), height 1.74 ± 0.11 m (range 1.47–1.94), weight 90.0 ± 16 kg (range 48–128), and BMI 29.4 ± 4.2 kg/m^2 (range 21.9–39.6).

All subjects underwent 3 days of inpatient physical therapy after TKA, followed by 2 to 3 weeks of home physical therapy. Three to 4 weeks after surgery, subjects started 6 weeks of outpatient rehabilitation (2–3 times/week, mean 17 visits). Outpatient physical therapy included interventions designed to control pain and swelling, increase knee ROM, improve strength, and improve functional ability as described by Stevens, *et al*[26]. Data were collected for this prospective study at 2 timepoints: 2 weeks preoperatively and 12 months postoperatively. All subjects completed each assessment in the following order: (1) completion of self-report questionnaires, (2) determination of knee ROM, (3) performance based functional assessment, and (4) quadriceps strength assessment. The institutional review board approved the study and all subjects gave written informed consent.

Strength assessment. Quadriceps strength was measured isometrically using a burst superimposition technique[22,27]. In brief, subjects were seated in an electromechanical dynamometer (Kin-Com 500H, Kin Com, Chattecx Corp., Harrison, TN, USA) with the hip flexed to 90° and the knee flexed to 75°. The axis of the dynamometer motor was set to match the axis of rotation of the tibiofemoral joint, and the distal edge of the shin attachment was placed about 5 cm proximal to the lateral malleolus of the test leg. Both waist and trunk straps were used for stabilization. Subjects performed 2 submaximal contractions and one maximal voluntary contraction (MVC) lasting 2 to 3 seconds to familiarize themselves with the testing procedure.

After 5 minutes of rest, subjects were instructed to maximally contract the quadriceps for roughly 3 seconds. Verbal encouragement and visual force output were used to facilitate maximal volitional force production. Roughly 2 seconds into the contraction, an electrical stimulator (Grass S8800 with a Grass model SIU8T stimulus isolation unit; Grass Instruments, Braintree, MA, USA) delivered a supramaximal electrical stimulus to the quadriceps muscle. If maximum volitional force output was achieved and no augmentation of force was observed with the application of the stimulation (i.e., complete recruitment) testing was concluded for that limb. If augmentation was present during the application of the electrical stimulus, the test was repeated for a maximum of 3 trials. Five minutes of rest was provided between test contractions. The trial with the highest volitional force production was used for analysis and peak volitional knee extension force was used for analysis. The knee extension force was normalized by BMI. Burst superimposition testing was performed on uninvolved limb first followed by the involved leg. The burst superimposition technique has been shown to be highly reliable when determining isometric quadriceps strength with repeated testing in subjects without knee pathology [intraclass correlation coefficient (ICC) = 0.98][28], and has been used to quantify strength in prior investigations involving individuals with TKA[22,27].

Knee range of motion measurement. Available knee ROM was measured using a standard long-arm goniometer. The axis of the goniometer was aligned with the center of the lateral epicondyle of the femur. The distal arm of the goniometer was aligned with the lateral malleolus, and proximal arm was aligned with the greater trochanter of the femur. Knee flexion ROM was the value of maximal active bending of the knee while the patient was lying supine. Knee extension ROM was the angle of maximal active straightening as the patient's heel was propped on a 10 cm wooden block. If a patient achieved hyperextension during knee ROM assessment, then the degrees of extension beyond zero were recorded as a negative value. Examination of knee ROM in patients with knee OA has adequate reliability, with a coefficient of 0.96 for flexion and 0.81 for extension[29].

Functional performance tests. Measures of functional performance included the Timed Up and Go (TUG) test and a Stair Climbing Test (SCT). TUG measures the time it takes a patient to rise from an armchair (seat height 46 cm), walk 3 meters, turn, and return to sitting in the same chair. Subjects were asked to walk as quickly as they felt safe and comfortable. Subjects were allowed to use the arms of the chair to stand and sit down. The TUG is widely used to measure mobility in older adults. It has excellent interrater (ICC = 0.99) and intrarater reliability (ICC = 0.99), as reported in a group of 60 functionally disabled older adults (average age 80 yrs)[30].

The SCT measures the time it takes a subject to ascend and descend a flight of 12 steps (each step 18 cm high and 28 cm deep). Subjects were asked to complete the test as quickly as they felt safe and comfortable. The use of one handrail was allowed if necessary, but patients were encouraged to minimize their use of the handrail. For both the TUG and SCT, one practice test was performed and the average of 2 subsequent tests was used for analysis. Assistive devices were allowed only if the subject was unsafe or could not complete the test without the assistance of a cane or walker. Rejeski, *et al*[31] described the same test, but used 5 steps, and found the stair climb task had excellent test–retest reliability (coefficient of 0.93). The task of stair climbing has been found to be sensitive to change with interventions in individuals with knee OA[32].

Health status questionnaires. Health status questionnaires were completed by all subjects at the time of strength assessment. The Medical Outcomes Survey Short Form 36 (SF-36) was used as a general health outcome measurement. The SF-36 is a commonly used generic health measure and has been repeatedly included in assessments of patients with TKA and knee OA[7,8]. This questionnaire covers 8 domains of health: physical function, bodily pain, role physical, general health, vitality, role emotional, social function, and mental health. The physical component summary (PCS) and mental component summary (MCS) represent a composite score for the respective physical and mental domains of the questionnaire. The PCS and MCS scores are norm-based scores where an average of 50 and a standard deviation of 10 represent the general US population[33]. The PCS and MCS scores were chosen for analysis as they represent a composite of physical and mental health. The SF-36 was selected for use in this study as it is reliable, internally consistent, and easy to administer[7,33,34].

The Knee Outcome Survey/Activities of Daily Living Scale (KOS-ADLS) is a 14 item questionnaire with items designated to assess how knee symptoms and knee condition affect the ability to perform daily functions[35]. A maximum of 5 points is allotted to each item. Scores are presented as a percentage of the maximal total score, 100% representing full perceived knee function for activities of daily living. This questionnaire has been shown to have excellent psychometric properties (test-retest reliability ICC = 0.97), including superior responsiveness to treatment for patients with disorders of the knee[35,36].

Pain assessment. The influence of the subject's pain on functional tasks was measured using the bodily pain score from the SF-36 Health Survey. This score was derived from 2 questions (11-level scale) of the questionnaire that query the subject's intensity of bodily pain or discomfort and measures the extent of the interference with normal activities due to pain. Scores are transformed into a zero to 100-point scale, where 100 represents the best score possible. The bodily pain score was selected because (1) it is a commonly used pain assessment; (2) it was expected to produce a wide range of preoperative scores; and (3) the score represents both the intensity of pain and how pain influences daily activities. Bodily pain has a good test-test reliability coefficient of 0.85 within the general population[37].

Data management and analysis. Significant differences in means between the 2 testing sessions for the impairments and outcome measures were assessed using paired t tests. The independent variables include the preoperative involved quadriceps strength, preoperative bodily pain score, age, and preoperative knee flexion ROM. The dependent variables were the time on the SCT and TUG at one year after surgery and KOS and PCS scores. Pearson correlation coefficients were calculated to determine the relationship between age, preoperative quadriceps strength, preoperative bodily pain, and preoperative knee flexion ROM.

The ability of the independent variables to predict the dependent variables was analyzed using separate hierarchical linear regressions for each of the 4 dependent variables (TUG, SCT, KOS, and PCS). Hierarchical analysis was used to test 4 models for predicting each postoperative outcome measure. The first model included only age. The second included age and preoperative knee flexion ROM. The third model included age, preoperative knee flexion ROM, and bodily pain score from the SF-36. The final model included the addition of preoperative quadriceps strength. With each progressive step in the regression analysis the significance of the change in resultant R^2 value was analyzed with an F test. Adding preoperative quadriceps strength last to the predictive model controls for the previous predictive factors. The resultant F test comparing the third and final models would show if the inclusion of quadriceps strength significantly improves the ability to predict postoperative function.

All analysis was performed using SPSS software for Windows (v. 12.0; SPSS Inc., Chicago, IL, USA). An alpha level of 0.05 was used to determine significance.

RESULTS

The impairments of bodily pain and knee extension ROM improved significantly ($p < 0.001$; Table 1) from the preoperative condition, whereas quadriceps strength and knee flexion ROM were not significantly changed between testing times ($p > 0.05$; Table 1). The SF-36 MCS score did not change from the preoperative to the one-year testing session ($p = 0.916$; Table 1), but the SF-36 PCS score and the KOS-ADLS score improved significantly after surgery ($p < 0.001$; Table 1). Subjects also achieved a significant improvement on the SCT and TUG performance based tests ($p < 0.001$; Table 1).

There were no significant correlations between any of the independent variables used in the regression analyses ($p > 0.05$; Table 2). The predictive models that included age, preoperative knee flexion ROM, and bodily pain did not explain or significantly predict any of the postoperative functional outcome measures (all $R^2 = 0.33$, all $p > 0.05$; Tables 3-6). The addition of preoperative quadriceps strength induced a significant change ($p < 0.001$) in the R^2 value of the predictive model for the TUG (Table 3) and SCT tests (Table 4). The final model accounted for 41% of the variance in the time taken to complete the one-year TUG ($R^2 = 0.414$, $p < 0.001$; Table 3) and 54% of the variance in the time taken to complete the SCT ($R^2 = 0.539$, $p < 0.001$; Table 4). The addition of preoperative quadriceps strength did not significantly change the R^2 value of the predictive model for the score on the one-year KOS-ADLS ($p > 0.05$) or the score on the SF-36 PCS ($p > 0.05$). None of the predictive models in this study were significant predictors of postoperative scores on KOS-ADLS or the SF-36 PCS ($p > 0.05$).

DISCUSSION

Preoperative quadriceps strength proved to be a strong predictor of one-year postoperative functional performance-based measures from among the common impairments measured preoperatively in patients scheduled for TKA. Quadriceps strength and knee flexion ROM returned to preoperative values, while knee extension ROM improved at the longterm measurement. There was a dramatic reduction in bodily pain and a substantial improvement in self-assessment questionnaire scores one year after surgery. Quantitative assessment of function using timed tests improved, but not to the same degree as the self-assessment questionnaires. These findings are consistent with the best outcomes reported by others for patients who have undergone TKA[7,12,33,38,39].

Table 1. Mean ± standard deviation (range) of impairments and functional outcomes.

Variable	Preoperative	One Year	p
Involved quadriceps MVIC	19.42 ± 8.26 (2.98–41.23)	21.11 ± 9.50 (5.22–41.34)	0.127
Knee flexion ROM	121.0 ± 10.7 (97–141)	119.2 ± 11.7 (80–138)	0.472
Knee extension ROM	2.5 ± 3.6 (4 hyper–12)	0.4 hyper ± 2.7 (5 hyper–8)	< 0.001
Bodily pain	41.1 ± 16.0 (0–74)	79.6 ± 17.5 (41–100)	< 0.001
KOS-ADLS, %	53.5 ± 17.2 (18.6–88.6)	87.0 ± 9.3 (64.3–100.0)	< 0.001
SF-36 PCS	33.1 ± 8.2 (15.9–45.8)	48.3 ± 8.4 (28.7–60.4)	< 0.001
SF-36 MCS	57.0 ± 8.5 (36.7–69.7)	57.2 ± 5.2 (43.9–64.7)	0.916
TUG	9.70 ± 2.31 (5.46–15.15)	7.53 ± 1.66 (4.68–12.82)	< 0.001
SCT	19.55 ± 9.91 (7.74–55.7)	11.60 ± 3.54 (6.41–22.99)	< 0.001

Quadriceps strength (maximal voluntary isometric contraction, MVIC) is represented as extension force normalized to body mass index [newtons/body mass index (weight, kg/height, m^2)], maximal knee range of motion (ROM) is given in degrees, and bodily pain score from the SF-36 (0–100 point scale where a higher score in bodily pain represents improvement). Short-form 36 (SF-36) physical summary score (PCS) and mental summary score (MCS) (population mean = 50 ± 10) and the Knee Outcome Survey-Activities of Daily Living Scale (KOS-ADLS) (100% = perfect score). The performance based functional tests include the Timed Up and Go test (TUG) and stair climbing test (SCT). Times on the tests are reported in seconds and less time on the test represents better performance.

Table 2. Correlation matrix relating the predictors used in the regression analysis.

	Age	Knee Flexion ROM	Bodily Pain (SF-36)
Knee flexion ROM	0.235 (p = 0.144)		
Bodily pain (SF-36)	0.226 (p = 0.161)	0.141 (p = 0.386)	
Quadriceps strength	0.009 (p = 0.955)	0.031 (p = 0.848)	0.146 (p = 0.369)

ROM: range of motion. SF-36: Short-Form 36 questionnaire. The Pearson correlation coefficient is provided for.

Table 3. Comparison of regression models used to predict performance on the year Timed Up and Go test.

Model	r	R^2	R^2 Change	F Change	df	Significant F Change
Age	0.106	0.011	0.011	0.428	1, 38	0.517
Age + Flex ROM	0.225	0.051	0.040	1.545	2, 37	0.222
Age + Flex ROM + Bodily pain	0.229	0.052	0.002	0.060	3, 36	0.808
Age + Flex ROM + Bodily pain + Quadriceps strength	0.643	0.414	0.361	21.563	4, 35	< 0.001

df: degrees of freedom; ROM: range of motion.

Table 4. Comparison of regression models used to predict performance on the year Stair Climbing Test.

Model	r	R^2	R^2 Change	F Change	df	Significant F Change
Age	0.139	0.019	0.019	0.745	1, 38	0.393
Age + Flex ROM	0.252	0.064	0.044	1.757	2, 37	0.193
Age + Flex ROM + Bodily pain	0.260	0.068	0.004	0.151	3, 36	0.700
Age + Flex ROM + Bodily pain + Quadriceps strength	0.734	0.539	0.471	35.771	4, 35	< 0.001

df: degrees of freedom; ROM: range of motion.

Preoperative quadriceps strength contributed substantially to the prediction of both the performance based measures. The greatest change in predictive ability of the regression models occurred with the most physically demanding activity, stair climbing. That the inclusion of preoperative quadriceps strength improved the predictive models for the one-

Table 5. Comparison of regression models used to predict performance on the year Knee Outcome Survey–Activities of Daily Living Scale (KOS-ADLS).

Model	r	R^2	R^2 Change	F Change	df	Significant F Change
Age	0.104	0.011	0.011	0.417	1, 38	0.523
Age + Flex ROM	0.136	0.018	0.008	0.287	2, 37	0.595
Age + Flex ROM + Bodily pain	0.216	0.047	0.028	1.070	3, 36	0.308
Age + Flex ROM + Bodily pain + Quadriceps strength	0.377	0.142	0.095	3.876	4, 35	0.057

df: degrees of freedom; ROM: range of motion.

Table 6. Comparison of regression models used to predict performance on the year SF-36 physical component summary (PCS).

Model	r	R^2	R^2 Change	F Change	df	Significant F Change
Age	0.244	0.060	0.060	2.415	1, 38	0.128
Age + Flex ROM	0.244	0.060	0.000	0.001	2, 37	0.982
Age + Flex ROM + Bodily pain	0.330	0.109	0.049	1.992	3, 36	0.167
Age + Flex ROM + Bodily pain + Quadriceps strength	0.344	0.118	0.009	0.364	4, 35	0.550

df: degrees of freedom; ROM: range of motion.

year TUG and SCT tests, from accounting for less than 10% of the variance to accounting for essentially half the variance, is remarkable. While pain is one of the major indications for TKA[40], bodily pain was not predictive of any of the one-year functional outcome measures. Similarly, achieving full extension and providing adequate knee flexion ROM for functional tasks is a postoperative goal, yet the amount of preoperative knee ROM did not predict postoperative function.

While preoperative quadriceps strength was an important predictor of the performance based outcomes, it did not contribute significantly to the predictive value of the model for the self-assessment functional outcomes. Indeed, none of the models in this study were good predictors of the postoperative self-assessment scores. Previous research has shown that the preoperative self-assessment scores predict a significant amount of the variance in scores from longterm postoperative self-assessment[5,7,8]. Preoperative impairments of quadriceps strength, knee flexion ROM, and bodily pain scores appear to be inferior to preoperative self-assessment scores when predicting longterm outcomes in postoperative self-assessment scores.

Surgeons typically consider the longevity of the endoprosthesis in surgical planning. As revision TKA is not as predictably successful, surgeons would prefer the patient be old enough at the time of primary TKA to have the prosthesis last for the life of the patient. Consequently, symptoms are often quite severe and functional limitations are great at the time of TKA surgery. As quadriceps strength decreases with time in people with progressive knee OA[41], implementing TKA before development of substantial weakness may help to mitigate the current levels of postoperative disability. Our results support previous evidence[1,5,8] that delay in the decision to undergo TKA may limit the ultimate functional success of the surgery.

This investigation has limitations. Our sample has a relatively high percentage of men, which is not common in studies involving TKA. Men who undergo TKA have been reported to have physical function scores that are significantly greater than those of women[10,39,42], which may partially explain why our sample achieves a high level of functional performance at the postoperative assessment. Also, the pain assessment used for our analysis does not focus specifically on knee pain. The pain associated with other conditions may have influenced our findings. Finally, the sample size could be considered modest in comparison to previous research in TKA. We performed an *a priori* power analysis after completing the assessment for 19 subjects. Our focus in determining sample size was centered on the relationship between preoperative quadriceps strength and the results of the one-year performance based measures. Statistical power for these main effects with 19 subjects ranged from 0.805 to 0.96. We concluded that doubling that initial sample would allow us to investigate the combined influence of the variables we examined.

One of our main objectives was to provide direction for potential preoperative interventions that could influence residual postoperative disability after TKA. The strong prediction of functional outcome by preoperative quadriceps strength suggests that a preoperative intervention focusing on improving quadriceps strength may reduce residual disability after TKA. Efforts to improve pain management prior to TKA beyond those measures that allow for more rigorous exercise would likely be of little consequence to postoperative function, as they would be overshadowed by a profound positive influence of the surgery on bodily pain. Postoperative knee ROM has been related to preoperative ROM[38]; however, our data suggest that intervening to enhance preoperative knee flexion would have little bearing on the majority of functional tasks for patients after TKA.

Exercise programs that include quadriceps-strengthening exercise not only improve quadriceps strength, but they lessen pain and improve functional ability in individuals with knee OA[32,43-46]. In general, studies that have shown the more dramatic improvements in strength prescribe a progressive, high intensity exercise prescription that lasts longer than 8 weeks. Most of these interventions have been initiated in individuals during the beginning stages of knee OA. People with severe joint space loss, as in those awaiting TKA, have a more modest improvement with strengthening protocols[47,48].

We reported[22] that quadriceps strength decreases precipitously after TKA, with patients losing roughly 60% of their strength over a one month period. The recovery of quadriceps strength after TKA is not predictable. In this sample, subjects recovered to preoperative levels by one year after surgery, and their preoperative strength was the strongest predictor of function at one year after TKA. Quadriceps strength is responsive to intervention after surgery, but the 2 studies that performed quadriceps strength assessment in conjunction with preoperative TKA rehabilitation interventions reported no substantial influence of preoperative exercise on postoperative outcome[49,50]. The preoperative treatment prescriptions generally consisted of stretching and isometric exercises or cardiovascular training over a period of 4 or 6 weeks. The exercise directed at the quadriceps was low intensity (e.g., quadriceps setting) and quadriceps strength was not significantly altered by preoperative intervention.

The results from these 2 investigations are puzzling, as quadriceps strength was significantly improved in patients with knee OA with exercise intervention. The lack of improvement in strength with a preoperative intervention could be a product of an inadequate strengthening intervention or one that is applied too late in the deterioration of the joint. Our results emphasize the functional importance of instituting quadriceps strengthening early and stress the maintenance of quadriceps strength throughout the disease processes of knee OA. Even if the ultimate goal of slowing progressive symptoms and preserving function by early initiation of quadriceps strengthening in knee OA ends with TKA, the functional outcomes of surgery will likely be better in those individuals who maintained more quadriceps strength.

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