

Osteoarthritis of the Knee: Isokinetic Quadriceps Exercise Versus an Educational Intervention

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ABSTRACT. Maurer BT, Stern AG, Kinossian B, Cook KD, Schumacher HR Jr. Osteoarthritis of the knee: isokinetic quadriceps exercise versus and educational intervention. *Arch Phys Med Rehabil* 1999;80:1293-9.

Objective: To evaluate the effects of isokinetic exercise versus a program of patient education on pain and function in older persons with knee osteoarthritis.

Design: A randomized, comparative clinical trial, with interventions lasting 8 weeks and evaluations of 12 weeks.

Setting: An outpatient Veterans Affairs Medical Center clinic and an affiliated university hospital.

Patients: One hundred thirteen men and women between 50 and 80 years old with diagnosed osteoarthritis of the knee; 98 completed the entire assigned treatment.

Intervention: Patients received either a regimen of isokinetic exercise of the quadriceps muscle three times weekly over 8 weeks or a series of 4 discussions and lectures led by health care professionals.

Main Outcome Measures: Variables studied for change were isokinetic and isometric quadriceps strength, pain and function determined by categorical and visual analog scales, and overall status using physician and patient global evaluations by the Arthritis Impact Scale, version 2, Western Ontario McMaster's Arthritis Index, and Medical Outcome Study Short Form 36.

Results: Both treatment groups showed significant strength gains ($p < .05$), which occurred over a wider velocity spectrum for the exercise group. Exercised patients also had improved pain scores for more of the variables measured than those receiving education. Both groups had positive functional outcomes and slightly improved measures of overall status.

Conclusions: Isokinetic exercise is an effective and well-tolerated treatment for knee osteoarthritis, but a much less costly education program also showed some benefits.

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THE PAIN AND FUNCTIONAL losses associated with osteoarthritis (OA) are of increasing clinical concern. OA is probably the most common joint disorder^{1,2} and is the second leading cause of disability in older US residents.³ Radiographic evidence of OA in the knee, the most commonly affected weight-bearing joint, can be found in one third of the population between the ages of 63 and 94 years.⁴ Physical disability arising from pain and loss of functional capacity reduces quality of life and increases the risks of further morbidity and mortality.^{5,6}

Treatments for knee OA have included pain relief with analgesics and nonsteroidal anti-inflammatory drugs (NSAIDs), surgical correction, and conservative physical interventions. There is some evidence that NSAIDs may be overused,^{7,8} and the cost and risks associated with surgical correction make it a later resort for most patients. Many physical rehabilitation techniques have evolved by trial and error, but typically have not been systematically evaluated in controlled situations. Exercise, at least until recently, has been the most neglected component in the treatment of knee OA.⁹ Although some exercise programs are thought to be safe and effective,^{10,11} few data exist examining their effects on outcomes such as disability and activity limitation due to OA.¹² Ettinger and colleagues¹³ recently conducted a randomized exercise study that showed both aerobic exercise and resistance exercise to be more effective over 18 months on several outcome parameters than an educational intervention.

Knee OA is associated with a variety of pathophysiologic deficits, including joint instability,¹⁴⁻¹⁷ reduced joint range of motion (ROM),¹⁸ and disuse atrophy of the quadriceps muscle.^{14,15} In particular, the pain of knee OA was shown in a recent study to be strongly associated with decreased quadriceps strength, even after accounting for psychological factors.¹⁹ Quadriceps weakness is even present in very early joint degeneration, suggesting that it may be a primary risk factor for aspects of knee OA.¹⁶ The quadriceps is the primary stabilizer of the knee,²⁰ affording protection of the articular structures.²¹ Muscle strength in older persons with knee OA may be reduced by up to one third compared with age-matched controls.²² These strength declines are thought to primarily result from the atrophy of type IIB fibers,²³ which are responsible for the rapid production of power. Type IIB fibers have demonstrated the ability to hypertrophy after undergoing high tension and fatigue-inducing exercises.^{24,25} Since muscle weakness is correctable with appropriate rehabilitation,²² associated functional losses may be reversed.^{23,26}

Extended periods of inactivity caused by joint pain in arthritis patients can lead to disuse atrophy of the involved musculature²⁷ and can produce strength declines of up to 3% a week.²⁸ At present, however, there is insufficient evidence about which exercises are most effective in retarding or reducing physical disability.¹⁵ Several studies have demonstrated the arrest and reversal of type IIB fiber atrophy that was caused by steroid administration and inactivity, through the use of high velocity isokinetic training.²⁹ The precise mechanism by which isokinetic exercise strengthens the musculature has

been debated. Further, it is not known whether atrophy is more difficult to reverse with increasing age.

Resistive exercises have been used in various combinations in several studies involving arthritic knees. Combinations of exercises involving stretching, ROM, isometric, and isotonic techniques have been employed on lower extremities affected by knee OA.^{13,21,30,31} Results have suggested gains in both strength and function with some decline in pain. As for isokinetic training, strength increases have been documented for patients with rheumatoid arthritis.³²⁻³⁴ For patients with knee OA, few isokinetic training studies have been reported. Schilke and associates³⁵ presented results from a small sample of patients that suggested increased strength and mobility and reduced pain, although a control group receiving no intervention showed some improvement as well. In OA subjects, Kreindler and colleagues,³⁶ using control, "traditional quadriceps and hamstring strengthening exercise," and isotonic treatment groups for comparison, also demonstrated isokinetic exercise to increase strength, which was better maintained with a follow-up home exercise program.

Earlier studies have shown that the most rapid improvement in one activity is achieved through training in that activity or one that closely approximates it^{37,38}; this concept is known as selectivity. Isokinetic exercises offer great selectivity for the motions required in ambulation³⁷ and produce a faster rate of strength gain and reduced muscle tenderness than isotonic training.³⁷ Also, increases in heart rate and blood pressure may be of lesser magnitude than those occurring with isometric exercise,³⁹ which could be of particular importance among older OA patients who often present with comorbidities.

The present study evaluated the extent to which isokinetic quadriceps strengthening reduces pain and improves function in older persons with knee OA compared with the effects of an educational program. Isokinetic exercise was chosen for this study because of its previously demonstrated effect in other arthritis studies and its safety with less risk of elevated blood pressure. Efforts were focused on the quadriceps because these muscles have the greatest strength decline with disease compared with the other lower extremity muscles. Educational regimens of various types have also been described to help patients manage knee OA.³⁶ We hypothesized that isokinetic exercise would produce clinically meaningful improvements in pain and function in older persons with knee OA compared with a group receiving only educational intervention.

METHODS

A total of 113 patients were randomly assigned to receive an 8-week program of either isokinetic knee exercise three times weekly or a total of four classes on OA education and self-management. Patients were included if they met the current American College of Rheumatology (ACR) criteria for knee OA,⁴¹ were between 50 and 80 years of age, were receiving no drugs for their arthritis other than stable doses of analgesics or NSAIDs, had mild to moderate knee pain for at least the previous 3 months, and scored 1, 2, or 3 on the Kellgren radiographic scale.⁴² According to the Kellgren scale, standing anterior/posterior, and lateral X-rays enable the physician to classify knee OA into four grades: 0, normal; 1, doubtful narrowing of joint space, possible osteophytes; 2, definite osteophytes, absent or questionable narrowing of joint space; 3, moderate osteophytes, definite narrowing, some sclerosis, possible deformity; 4, large osteophytes, marked narrowing, severe sclerosis, definite deformity. To participate in the study, patients had to have a least one osteophyte other than at the tibial spine with severity below Kellgren grade 4.

Patients were excluded from the study if they were concur-

rently receiving physical therapy, were actively involved in any other pharmaceutical or exercise study or had undergone isokinetic strength training within the previous 3 years, had significant cardiovascular disease, had more than mild knee swelling, or had large popliteal cysts, knee instability, major knee or hip surgery on the side to be treated, systemic disease other than OA that might affect muscle function, severe osteopenia, a history of fracture in the area of the joint to be treated, or paresis of the lower extremity. Although several methods were used to recruit patients, most patients were involved from direct physician referrals from clinics affiliated with this study. A review of all recruitment methods used is described elsewhere.⁴³

Pain and Functional Assessments

Patient self-assessments were based on the Arthritis Impact Measurement Scales, version 2 (AIMS2), the Short Form, 36-item version of the Medical Outcome Study scales (SF-36 MOS) and Western Ontario McMaster's Arthritis Index (WOMAC) questionnaires. Each of these instruments quantifies pain level and difficulty in performing activities of daily living (ADL). AIMS2 is an arthritis-specific measure⁴⁴ and the SF-36 is a generalized health outcome survey.⁴⁵ Both forms use Likert scales with various questions on pain severity and functional disability and the SF-36 also measures overall health status. The AIMS2 captures patient-assessed status measures involving mobility, walking and bending, extremity function, household and self-care tasks, bodily pain, and social and psychological factors. Subscales in the SF-36 pertain to physical functioning, role-physical, role-emotional, bodily pain, general health, vitality, social functioning, and mental health. Analyses of these categorical data produce scored results for the overall instruments and for their respective subscales. WOMAC is specific to knee arthritis and contains visual analog scales with questions to assess the degree of pain, stiffness, and difficulty encountered with ADL.⁴⁶ For each question in the WOMAC, patients are asked to provide assessments for the target joint based on the previous 48 hours' experience. The position of the response (marked as an "X" on the scale) is measured in millimeters, and the values for each question are added to provide the overall and subscale results.

Additional pain assessments were made during walking and stair climbing. Patients walked 50 feet at self-selected moderate and maximum paces, and ascended and descended a standard half-flight of stairs, with pain assessed using 10-point scales where 0 indicated no pain. They were also asked to respond on a scale of 1 to 4 (1, not at all; 4, greatly) to the question, "Overall, how much does your knee limit your ability to perform your daily activities?" At the conclusion of the treatment period (week 8), patients were asked about pain changes in the knee under study; responses were on a scale of 1 to 5 (1, less pain now; 2, slightly less pain now; 3, no difference; 4, slightly more now; 5, much more pain now). Two similar additional questions were asked to assess changes in mobility and independence. (The questions asked at week 8 were adapted with permission from the Baltimore Hip Replacement Study questionnaire.)

At the initial screening, a medical history was taken for each subject. Clinical findings (disease duration, pattern of involved joints, and duration of morning stiffness) and treatments before and at the time of investigation were recorded. Evaluation for each subject, performed by a blinded investigator at baseline, at week 8, and at week 12 follow-up, included knee ROM measured with a goniometer, the heel-to-buttocks distance measured by tape measure at maximal knee flexion, and the presence or absence of joint effusion determined by palpation or presence of a bulge sign.

The side to treat was determined by physician investigator's assessment of pain and function, with each graded from 0 (no pain or functional compromises) to 4 (severe, disabling pain rendering the patient inactive). If neither leg had pain and functional limitations within the range of 1 to 3, the patient was excluded from the study. If the response value was different between the two limbs, the side with the higher score was chosen for treatment. If the values were the same, the Kellgren scale for X-ray findings was used (again with a range of 1 to 3 for inclusion).⁴² If that scale also yielded no difference, the patient was asked which side he or she preferred to have treated. Patients were assigned by a random number generator to either the exercise group, which received isokinetic training for 8 weeks, or to the education group, which was tested without formal exercise training. This randomization schedule was based on stratification by disease severity, determined by physician assessment of patient status and the Kellgren X-ray scale.

Overall Outcome

Measures of overall outcome used were the total WOMAC score (pertaining to pain, stiffness, and difficulty with ADL), overall assessments of patient status and treatment effectiveness made by the masked physician and the subject, and the MOS overall score. The MOS overall score was a composite of all the SF-36 subscales. A physician patient status assessment was made separately for each knee, based on the extent to which, in the physician's judgment, the patient's pain limited his or her activity level. At the 8-week visit, overall treatment effectiveness assessments were made by the patient and the physician. The categories for this response were: ineffective, minimally effective, effective, and very effective.

Muscle Assessments

The tester was masked as to each subject's intervention assignment. To determine which knee was more severely affected, muscle strength was measured on both sides by finding peak isokinetic torque on a dynamometer.^a Testing was performed at baseline and then at 4, 6, 8, and 12 weeks. The 12-week test assessed short-term maintenance of strength changes beyond the 8-week intervention period. The dynamometer angular velocities were 90°/sec and 120°/sec. Each subject extended the knee joint with maximal effort for three repetitions at each velocity. Between each test extension for a given velocity, the subject rested for 15 seconds; between velocities, the subject rested for 2 minutes. Additionally, after resting isometric testing was conducted at a knee angle of 90° to assess the versatility of training effects, ie, whether isokinetic exercises can improve isometric strength as well. Extension strength of the studied side was measured first, followed by a 2-minute rest and testing of the other side.

Interventions

The subjects in the exercise group underwent strength training of the knee extensor muscle groups unilaterally with the dynamometer three times a week for 8 weeks. During the exercise sessions, a total of 27 repetitions were performed as three sets of three extensions at each of the following angular velocities: 90°/sec, 120°/sec, and 150°/sec. Between each set of three repetitions, the velocity was adjusted while the subject rested for 1 minute. The group not receiving exercise received an educational intervention as a minimal, standardized form of usual care. All such subjects were provided with educational information about OA. Several Arthritis Foundation pamphlets were distributed, and four lectures and discussions were

conducted. The program consisted of (1) a lecture by a rheumatologist on the disease process of OA and its clinical characteristics, (2) a video discussing joint protection and other OA self-management techniques, (3) a session on nutrition guidelines and a guide to relevant community services (provided by a dietician and social worker, respectively), and (4) a discussion led by a psychologist on coping with pain and disability.

Analysis

Sample size was initially estimated at 55 patients per group, using AIMS pain data for patients with hip OA,^{47,48} with a 15% improvement as the threshold for a clinically meaningful outcome, and a predicted attrition rate of 20%. Once the study was underway, we re-estimated the sample size using our preliminary data, according to a method known as the EM algorithm,⁴⁹ where a stable estimate of the variance was obtained without a priori estimates of treatment differences. Since no distinction was made regarding treatment group, the analysis was blinded to this information. The revised estimate was 51 patients per group, indicating that the original value was reasonable.

To compare changes from baseline to week 8, between-group differences were assessed using *t* tests, and within-group differences were assessed by paired *t* tests. Linear regressions were performed to determine any relationships between the outcome measures and extension torque at 120°/sec.

RESULTS

Study population. Table 1 provides the demographic characteristics of the subjects in both the exercise and education groups. Of the 113 who enrolled, 15 either dropped out or were excluded some time after being randomized to one of the treatment groups. In none of these cases was termination believed to be caused by a study-related event; increased pain was the reason for four subjects, but neither subjects nor investigators attributed the pain to the treatment. The numbers listed for sex, age, body weight, and disease duration are based on the total number of subjects enrolled. No significant between-group differences were observed for measures of age, body weight, or disease duration.

Quadriceps muscle strength. The data in table 2 show the gravity-adjusted torque values for knee extension isometrically and for the isokinetic angular velocities of 90°/sec and 120°/sec. Exercise of the affected knee produced significant isometric and isokinetic strength gains. Education group subjects also showed significant improvements in isometric and 90°/sec extension torque. No differences between the groups were detected at baseline or at week 8. The "change" variable refers to the average of all subject's strength changes from baseline to week 8 for each group, not merely the subtraction of the mean values. The table indicates that both the exercise and education

Table 1: Subject Characteristics

	Exercise Group	Education Group
Enrolled subjects (<i>n</i>)	57	56
Completed the study (<i>n</i>)	49	49
Men (<i>n</i>)	30	36
Women (<i>n</i>)	27	20
Age (yrs)	66.3 (8.8)	64.5 (8.4)
Body weight (lb)	183.8 (32.8)	190.4 (35.0)
Disease duration (yrs)	9.7 (9.0)	13.1 (11.7)

Age, body weight, and disease duration reported as mean (standard deviation).

Table 2: Strength Variables

	Exercise (Group 1)	Education (Group 2)
Isometric extension torque (Nm/kg)		
Baseline	30.00	27.89
Week 8	36.12	33.01
Change, baseline to week 8	6.06*	6.30*
Week 12	37.62	34.31
Change, week 8 to week 12	2.90	1.03
Extension torque at 90°/sec (Nm/kg)		
Baseline	23.68	21.57
Week 8	28.35	25.03
Change, baseline to week 8	4.22*	3.51*
Week 12	28.65	23.84
Change, week 8 to week 12	-.14	-.75
Extension torque at 120°/sec (Nm/kg)		
Baseline	22.00	20.56
Week 8	25.53	22.22
Change, baseline to week 8	3.25*	1.97
Week 12	24.98	23.21
Change, week 8 to week 12	-1.04	.70

No significant between-group differences ($p < .05$) were observed.
* $p < .001$.

groups demonstrated strength gains, although in the exercise group this gain was seen over a wider velocity spectrum.

Pain. Table 3 shows the results for all of the pain variables used in the analysis. The WOMAC and MOS variables refer to the relevant pain sections in those respective instruments. The remaining variables are based on pain self-assessments during walking at a moderate pace, walking at a maximum pace, and ascending a half-flight of stairs. Pain variables that had a statistically significant improvement for the exercise patients were the WOMAC pain subscale, 50-foot moderate walk pain, and stairs pain. For the education group, the WOMAC and MOS subscales showed improvement. The only between-group differences occurred for "Pain Change" ($p = .007$) and Stairs Pain ($p = .02$) at week 8, favoring patients receiving exercise.

Joint findings. There were no between-group differences in joint findings. Surprisingly, a decrease in ROM occurred for both groups over the treatment period. Although not statistically significant, the percentage of patients in the exercise group with knee effusion declined from 39% to 25%, while the corresponding percentage in the education group decreased only minimally.

Function. Both groups reported some improvement in function (table 4). The baseline categorical value of 2.65 for group 1 indicates that the mean response fell between 2 ("slightly limited") and 3 ("moderately limited"). Although not significant, a greater trend toward improved mobility was seen in patients in the exercise group (56% vs 39%, $p = .09$). The AIMS subscale results were inconsistent, as is discussed below. According to the "ADL" categorical question and WOMAC, functional changes were better maintained by the education group during the four-week follow-up.

Overall outcome. WOMAC appeared to be a more sensitive measure of change for this population, most closely following the within-group self-reports of better outcomes ($p = .08$), compared with the SF-36, which showed little impact on function.

Regression analyses. Linear regressions using extension torque at 120°/sec showed that increased strength, which was the only strength measure that improved, was related ($p < .05$) to reduced pain (WOMAC section A), to improved function

(WOMAC section C, as well as AIMS and SF-36), and to overall outcome (WOMAC total score).

DISCUSSION

Quadriceps strengthening was clearly achieved by isokinetic exercise as given in the regimen described. The education group also demonstrated increases in muscle strength, however, except at 120°/sec. These findings can lead to speculation about the possible causes for strength changes in the education group. A review by Lorig and colleagues⁵⁰ indicated that education interventions for OA can increase knowledge of the disease process, joint protection, and self-management strategies, knowledge that is usually well maintained. Whether subjects in the education group independently pursued exercise regimens or otherwise implemented the information imparted after the study period was not recorded. The provision of information, such as the Arthritis Foundation pamphlets, may have encouraged increased activity levels.¹³ The use of no intervention at all might have eliminated these factors, but the attention and socialization paid to the exercise patients would then not have been controlled for.¹³ In one study where an intervention-free control group was used,³⁵ some strength increases were also noted for the controls, although there were no improvements in pain, stiffness, or mobility.

Other possible factors contributing to the education group's improvements might include the learning curve for use of the dynamometer and the fact that these subjects were tested on the

Table 3: Pain Variables

	Exercise (Group 1)	Education (Group 2)
WOMAC Section A (mm)		
Baseline	191.28	191.88
Week 8	143.79	167.11
Change, baseline to week 8	-43.54*	-28.49
Week 12	121.88	149.88
Change, week 8 to week 12	-13.77	-18.07†
"Pain Change" (categorical)		
Week 8: Raw Score	2.14	2.66
Week 8: % Improved	65%	36%
50' Moderate Walk Pain (categorical)		
Baseline	2.67	2.65
Week 8	1.84	2.90
Change, baseline to week 8	-.63†	-.10
Week 12	2.09	2.85
Change, week 8 to week 12	.15	-.28
50' Maximum Walk Pain (categorical)		
Baseline	2.88	3.43
Week 8	2.64	4.09
Change, baseline to week 8	-.06	.30
Stair Pain (categorical)		
Baseline	3.78	3.51
Week 8	2.42	3.58
Change, baseline to week 8	-1.50*	-.10
Week 12	3.09	3.59
Change, week 8 to week 12	.56	-.53
MOS Pain (categorical)		
Baseline	47.58	43.72
Week 8	52.07	48.11
Change, baseline to week 8	3.73	5.87‡

Between-group differences: "Pain Change" % Improved ($p = .007$) and Stair Pain at week 8 ($p = .02$), favoring the exercise group.

* $p < .001$.

† $p < .05$.

‡ $p < .01$.

Table 4: Function Variables

	Exercise (Group 1)	Education (Group 2)
"ADL" (categorical)		
Baseline	2.65	2.79
Week 8	2.08	2.40
Change, baseline to week 8	-.53*	-.38†
Week 12	2.45	2.55
Change, week 8 to week 12	.33†	.09
MOS Physical Function (scored)		
Baseline	47.83	46.85
Week 8	50.34	49.20
Change, baseline to week 8	1.04	4.10
WOMAC Section C (mm)		
Baseline	643.4	679.9
Week 8	541.1	591.1
Change, baseline to week 8	-88.3‡	-106.9†
Week 12	464.4	606.6
Change, week 8 to week 12	-20.8	8.6
AIMS Mobility (scored)		
Baseline	1.72	1.54
Week 8	.94	1.45
Change, baseline to week 8	-.59*	.18
Week 12	1.28	1.21
Change, week 8 to week 12	.32†	-.42
AIMS Walk & Bend (scored)		
Baseline	4.74	4.95
Week 8	4.50	3.86
Change, baseline to week 8	.01	-1.14*
"Independence Change" (categorical)		
Week 8: Raw Score	3.64	3.40
Week 8: % Improved	44%	28%
"Mobility Change" (categorical)		
Week 8: Raw Score	3.73	3.52
Week 8: % Improved	56%	39%

Between-group differences: AIMS Mobility Change, baseline to week 8 ($p = .02$) and AIMS Walk and Bend Change, baseline to week 8.

* $p < .001$.

† $p < .01$.

‡ $p < .05$.

Biodex four times in the 8-week period, in a manner similar to the actual exercise regimen. In contrast, control patients in the Schilke study³⁵ used the dynamometer only twice—at the beginning of the 8-week period and at the end. Interaction with the machine may have been sufficient to produce some training effects.

Educational interventions have received increasing attention in recent years, as an adjunct to conventional therapy or even as a stand-alone treatment. The relative simplicity and low cost of implementing such programs make this approach appealing. Studies on education of arthritis patients have suggested improvements in some aspects of pain, self-efficacy, and functional status.⁵⁰⁻⁵³ Since self-care education is thought to reduce health care utilization and costs for this population,⁵⁴ economic benefits may be an added positive outcome. For mild OA, early interventions could focus on education alone, or education in conjunction with other nonpharmacologic approaches such as exercise and physical therapy.⁵⁵

Both isokinetic and education groups also had improved pain scores, but the trend was toward more successful pain reduction in the exercise group. Significant between-group differences favoring exercise were noted for stairs pain as well as for the "Pain Change" variable. It seems that isokinetic exercise may

be of particular benefit for the task of stair climbing. Overall, pain reduction appeared to favor the exercise group.

We have been interested in whether synovial effusions might identify subsets of OA patients needing different treatment.⁵⁶ While not statistically significant, it may be of some clinical importance that the percentage of subjects with effusion decreased by 14% in the exercise group but did not change for the education group. Concerns that high-intensity isokinetic training might exacerbate joint pain and effusion in this population⁵⁷ are apparently unfounded, and this concurs with at least one earlier finding.³² It is difficult to interpret why both groups demonstrated significant decreases in ROM over time. A more extensive analysis of this variable could clarify these findings. Perhaps augmenting the treatment with a physical therapy program including stretching and ROM exercises might produce improvements in joint movement, since such interventions have had this effect in other studies.^{9,25,30,31,36}

The functional outcomes, combining all the variables listed in table 4, clearly show that both groups improved. It was surprising that the AIMS2 Mobility and Walk/Bend subscores were so different between the two groups, since both pertain to function, but perhaps this is one way of assessing which specific functional tasks might best respond to a particular mode of therapy.

Although isokinetic training clearly had some impact on strength and pain, it had no incremental effect on function as assessed by the WOMAC, the SF-36, or the AIMS2 questionnaires. Further, linear regressions showed that only the WOMAC was affected by strength (measured as torque at 120°/sec). These regressions suggest that any functional gains accrued from improved strength were modest at best. They also suggest that the WOMAC might be a more sensitive instrument to measure the impact of strength on pain and functional changes. This conclusion is supported by a recent assessment of health status instruments used in OA patients⁵⁸ in which the WOMAC was far more sensitive to change than the SF-36.

The results of this study might have been different, or perhaps easier to interpret, if all knees with symptomatic OA had been treated. The experimental design used (ie, limiting treatment to the more involved side) was probably not optimal to improve overall function in some patients with bilateral knee OA. Bilateral training might have been preferable, and isometric and isokinetic testing data for the contralateral side might also have provided a useful control. Since the symptoms of OA may be present either unilaterally or bilaterally in the knees, no consensus has formed among physical intervention studies to date regarding whether to treat one side or both. In the studies conducted by Schilke,³⁵ Fisher,³⁰ and Feinberg,³¹ both knees were treated in all subjects. Jan and Lai⁵⁹ treated 94 knees in 61 subjects, focusing only on symptomatic knees. In practice with an intensive, costly exercise regimen as used here, treating only the symptomatic knee would seem reasonable.

A procedure for repeated testing (ie, obtaining a second recording of peak torque) would have provided more confidence in the strength measures used in the analysis. Other studies^{34,60,61} have included some provision for repeated testing to demonstrate the reproducibility of their findings. Gravitational forces, increasing age, and muscle weakness from disability may affect the accuracy and/or precision of dynamometric torque readings.⁶¹⁻⁶³ These factors may be especially important for arthritis patients with muscle weakness, for whom a single strength reading might be less reliable.⁶¹

CONCLUSION

The results of this study show that isokinetic strengthening was of benefit to OA patients, particularly in reducing pain. The

Table 5: Measures of Overall Outcome

	Exercise (Group 1)	Education (Group 2)
WOMAC Total (mm)		
Baseline	915	950
Week 8	724	827
Change, baseline to week 8	-153*	-156†
Week 12	668	785
Change, week 8 to week 12	-20	18
Patient Evaluation (categorical)		
Week 8	1.69	1.34
Doctor Evaluation (categorical)		
Week 8	1.50	1.28
MOS Overall (scored)		
Baseline	101.0	100.5
Week 8	102.8	100.2
Change, baseline to week 8	1.7	2.4

No significant between-group differences ($p < .05$) were observed.

* $p < .001$.

† $p < .01$.

regimen was safe, effective, and well tolerated. The educational intervention also produced substantial benefits at a much lower cost. Inclusion of patient education in early OA interventions would seem feasible; studies should be developed to evaluate the incremental value of exercise in addition to an educational program. The relationship of strength to improved function would suggest some incremental gain from exercise added to a stretching and education program. A recent study conducted over 18 months showed less benefit from a different educational regimen than from two types of exercise.¹³ Details of exercise and education regimens will need more consideration in future investigations.

Our efforts represent the first extensive research on the utility of isokinetic exercise for quadriceps strengthening in OA of the knee, fulfilling a need stated previously⁶⁴ to rigorously analyze each specific mode of resistive exercise. Comparing our findings with those of past and future studies on other rehabilitative techniques should help establish sound guidelines for optimally efficient delivery of the most effective conservative interventions.

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