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ORIGINAL ARTICLE

A Comparison of Strength Training, Self-Management, and the Combination for Early Osteoarthritis of the Knee

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Objective. **To assess the relative effectiveness of combining self-management and strength training for improving functional outcomes in patients with early knee osteoarthritis.**

Methods. **We conducted a randomized intervention trial lasting 24 months at an academic medical center. Community-dwelling middle-aged adults (n = 273) ages 35–64 years with knee osteoarthritis, pain, and self-reported physical disability completed a strength training program, a self-management program, or a combined program. Outcomes included 5 physical function tests (leg press, range of motion, work capacity, balance, and stair climbing) and 2 self-reported measures of pain and disability.**

Results. **A total of 201 participants (73.6%) completed the 2-year trial. Overall, compliance was modest for the strength training (55.8%), self-management (69.1%), and combined (59.6%) programs. The 3 groups showed a significant and large increase from pre- to posttreatment in all of the physical functioning measures, including leg press (d = 0.85), range of motion (d = 1.00), work capacity (d = 0.60), balance (d = 0.59), and stair climbing (d = 0.59). Additionally, all 3 groups showed decreased self-reported pain (d = −0.51) and disability (d = −0.55). There were no significant differences among the groups.**

Conclusion. **Middle-aged, sedentary persons with mild early knee osteoarthritis benefited from strength training, self-management, and the combination program. These results suggest that both strength training and self-management are suitable treatments for the early onset of knee osteoarthritis in middle-aged adults. Self-management alone may offer the least burdensome treatment for early osteoarthritis.**

INTRODUCTION

Osteoarthritis (OA) is the most common form of arthritis and the second-leading cause of long-term disability in the US (1). OA of the knee typically affects women more than men and has a prevalence between 10–15% at age 35 years and 35–45% at age 65 years (2). Currently the most prevalent chronic condition among women (3), OA warrants serious concern.

Aerobic and resistance exercise (4) and self-management (5,6) produce positive changes in objective functional and patient-reported outcomes for knee OA. These findings led the American College of Rheumatology to support both therapeutic approaches in their updated treatment guidelines (7). Most studies documenting these effects sample older patients and compare the two treatments with each other (8) or compare one with some form of treatment as usual (9). Older patient samples have longer disease durations, greater OA severity, and greater functional impairment; thus, they do not represent all patients with knee OA.

Three questions remain from the literature. First, would strength training or self-management produce significant improvements with younger, sedentary, and less disabled patients with mild knee OA? Although the combination of these characteristics describes the majority of patients with early knee OA, previous studies have not provided

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conclusive information on this typical combination because their samples captured only one or two of these features per study. Second, would combining the two treatments improve functional outcomes more than strength training or self-management alone? Recent meta-analytic results (10) explicitly omitted studies that combined the treatments, so there is scant evidence on the benefit of multidimensional treatments relative to strength training and self-management alone. Because both treatments may address physical and psychological functional outcomes differently, we hypothesized that combining the two treatments might enhance the outcomes. Third, would outcomes differ between objective or self-reported measures? In many cases, patient-reported outcomes differ from objective physical functioning measures (11).

The Multidimensional Intervention for Early Osteoarthritis of the Knee (Knee Study) was designed to test these questions directly by comparing strength training, self-management, and a combination of strength training and self-management for improving patients' physical functioning and pain measured by both objective tests and patient self-report.

PATIENTS AND METHODS

Design. The Knee Study was a 24-month unblinded randomized intervention trial to compare the effects of 3 interventions: a strength training program, a self-management program, and a combined strength training and self-management program. The study was conducted with Institutional Review Board approval in accordance with the Helsinki Declaration at the University of Arizona Arthritis Center in Tucson, Arizona. All of the study participants gave written informed consent prior to randomization. Two-hundred seventy-three participants were stratified by sex and randomly assigned by the project coordinator via a random number table to 1 of the 3 treatment groups.

Participants. The Knee Study participant eligibility criteria consisted of 1) between ages 35 and 64 years, 2) reported pain on most days in one or both knees, 3) duration of symptoms of less than 5 years, 4) Kellgren/Lawrence classification grade 2 radiographic evidence of knee OA in one or both knees (12), and 5) self-reported disability due to knee pain for at least 3 of the following: descending or ascending stairs, walking, kneeling, or performing daily activities.

Potential participants were excluded if they had 1) an uncontrolled medical condition that precluded safe participation or prevented completion of the study (e.g., heart disease, blood pressure, or respiratory conditions), 2) any neurologic condition that could affect coordination, 3) inflammatory arthritis (e.g., rheumatoid or psoriatic arthritis), 4) previous knee surgery, 5) Kellgren/Lawrence grade 3 or 4 radiographic evidence of OA in one or both knees, 6) a body mass index (BMI) >37.5 kg/m^2 (individuals over that limit were advised to follow a weight loss program and achieve a stable weight for 6 months prior to participation), 7) a knee corticosteroid injection in the previous 3 months, 8) plans to move from the local area, 9) plans to become pregnant during the study period, 10) more than 120 minutes per week of any vigorous (e.g., exercise, walking, household chores, etc.) physical activity, or 11) participated in any form of resistance training.

The staff recruited participants from the local community by mass mailings, television/newspaper advertisements, and flyers. After telephone screening by the study staff, individuals who met the initial eligibility criteria underwent a radiographic examination administered by a staff rheumatologist. Individuals meeting all of the eligibility criteria were followed for a run-in period (mean 73 days) after random assignment (via concealed computer-generated values) to one of the 3 treatment groups as described above.

Interventions. *Strength training.* Participants engaged in 2 phases of strength training. The first phase (9 months) of strength training sessions, supervised by expert physical trainers, targeted improvement in each of 3 core areas: 1) stretching and balance, 2) range of motion and flexibility, and 3) isotonic muscle strengthening. Subjects reported to the designated facilities for 3 sessions per week, and each session consisted of the following essential components: 1) 10-minute walking warm-up at 50% maximum heart rate, 2) 5–10 minutes of stretching and balance exercises, 3) 10 minutes of range of motion/flexibility exercises, 4) 30 minutes of strength training exercises, and 5) 5 minutes of cool-down, which included walking and/or static stretching of the muscles. For all of the strength training components, the subjects completed specified exercises with both extremities.

Isotonic loads were increased through 3 stages (body weight/therabands, free weights, and machine weights) according to each participant's needs, fitness, and current condition. In lieu of basing initial resistance on a 3- or 6-repetition maximum, all of the weights progressed from a comfortable resistance with proper exercise form. Participant load progression followed the following logic: all participants started at 2 sets of 6 repetitions and gradually increased to 2 sets of 10 repetitions at the same weight. When participants thought they could increase the weight and had completed the exercise for at least 2 consecutive strength training days, they would do so and shift back to 2 sets of 6 repetitions. Range of motion exercises were increased for each subject when the exercises could be completed with a Borg scale of difficulty ≤ 6 (13). Throughout the process, trainers emphasized good form and encouraged participants to note soreness or pain during and after exercises.

Phase 2 (15 months) focused on developing self-directed long-term exercising habits. The trainers contacted the participants every 2 weeks during the first 6 weeks of phase 2; thereafter, contact was reduced to every other month. During the first 6 weeks, trainers recorded compliance and adjusted exercise schedules to meet each participant's needs. In addition to scheduled sessions, trainers encouraged the participants to meet quarterly for booster sessions.

Self-management. Based on existing self-help programs (14), the 2-phase self-management intervention targeted coping and self-efficacy skills. The 9-month phase 1 consisted of 12 weekly 90-minute (60% didactic, 40% interactive) classroom sessions facilitated by the program manager and local health professionals; no strength training treatment staff were involved. These were followed by weekly telephone calls designed to boost knowledge and behaviors from classroom sessions, as well as provide practical, one-on-one problem-solving discussions to tailor the treatment to each participant's needs. These weekly phone calls continued through the end of phase 1 and also through phase 2, when they were staggered to biweekly, monthly, and then bimonthly calls. Coping skills focused on promoting more adaptive strategies and reducing avoidant or passive strategies. Self-efficacy skills focused on increasing perceptions of control for physical functioning, pain management, and other ancillary arthritis symptoms. One of the 12 lectures covered the lifetime health benefits of a well-balanced exercise program that included strength, flexibility, and aerobic conditioning, as well as suggested strategies for self-motivation to maintain such a regimen. Participants at this session received lists of exercise resources should they wish to establish their own regimens. Self-management group participants, however, received no instructions pertaining to specific exercises, techniques, or routines. Staff taught the self-management skills using educational and behavioral methods, including homework assignments and active involvement/practice during treatment sessions.

Combined treatment. The combined group concurrently participated in both the strength training and self-management courses, with slight alterations to ensure equivalence of contact time across the treatment groups. Specifically, the staff contacted the participants in the combined treatment group less often than the participants in the strength training and self-management programs during phase 2. Otherwise, the combined group participated in the full, independent treatment protocols for both the strength training and self-management programs.

Primary outcome measures. *Physical performance tests.* Objective measures of physical functioning consisted of 5 discrete physical performance tests measured 3 times (months 0, 9, and 24). Each test provided several metrics of performance, including time to complete, force, number of repetitions, etc., that were combined to a unit weighted Z score average to reduce the number of statistical tests and improve the reliability of each test (15). Higher values reflect greater functional ability. Expert disability assessors, physical trainers, and study staff administered the following tests for all of the groups according to standard protocols.

Leg press (maximum voluntary isometric lower body strength). The subjects sat on the quadriceps isometric force test device (test–retest reliability 0.99) (16,17) with both hip and knee angles at ~90 degrees. Expert disability assessors instructed the participants to build up to maximal pressure over 10 seconds to one foot as if they were straightening their leg from 90 degrees while keeping their backs flat against the back rest and hips down on the seat. The expert disability assessors recorded the maximum force for 3 trials with each leg along with perceived exertion at the conclusion of the test for each leg.

Functional range of motion (FOCUS). In this timed test (test–retest reliability 0.90) (18), subjects moved 18 pegs from one position to another in vertical, horizontal, and diagonal planes of a pegboard to demonstrate range of motion (e.g., from above the shoulders to below the knees, from a standing to a crouching position). The expert disability assessors recorded measures of perceived pain and exertion after testing.

ERGOS work simulator. The ERGOS (Tucson, AZ), administered by expert disability assessors (19), provided a standardized measurement of functional work capacity using computerized delivery of instructions and data collection of time, work load, perceived pain, and perceived work load. The ERGOS exercise consisted of grasping a series of 5-pound steel discs and moving them along a metal bar while in a crouching position (in 2 parts: from right to left and then left to right). Outcomes reflect the participant's ability to perform lower body and upper body coordinated movements typical in manual labor.

Get up and go. Physical trainers timed the participants while they rose from a seated position, walked 3 meters, turned 180 degrees, walked back to the chair, and sat down using regular footwear and a customary walking aid (20). The participants reported pain levels and perceived exertion after testing.

Stair climbing. Physical trainers timed the participants as they climbed and descended 5 steps for 3 trials (20). The participants also reported physical discomfort related to knee and quadriceps involvement.

Self-reported pain and disability. The patient self-report outcome measures, administered 5 times (months 0, 3, 9, 18, and 24), consisted of several scales combined to form standardized indices of pain and disability. Pain measures included a visual analog scale (VAS; range 0–100), the body pain subscale from the Short Form 36 (SF-36) (21), and the pain subscale from the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (22). Disability measures included the stiffness and disability subscales from the WOMAC, the physical function subscale from the SF-36, and a VAS (range 0–100) for arthritis disability. Similar to the physical performance tests, each set of measures was first standardized and then averaged to form a standardized index score. Higher values indicated greater pain and disability.

Secondary measures. There were several relevant covariates included prior to testing for treatment effects. Arthritis severity at baseline, measured by a self-reported VAS (range 0–100), age, sex, and BMI served as covariates. These variables often serve as excellent predictors of treatment outcome in knee OA treatment studies.

Statistical analyses. Our primary objective was to compare both self-reported outcomes (pain and disability) and physical performance test outcomes among the 3 treatment groups (whether the combined group performed better

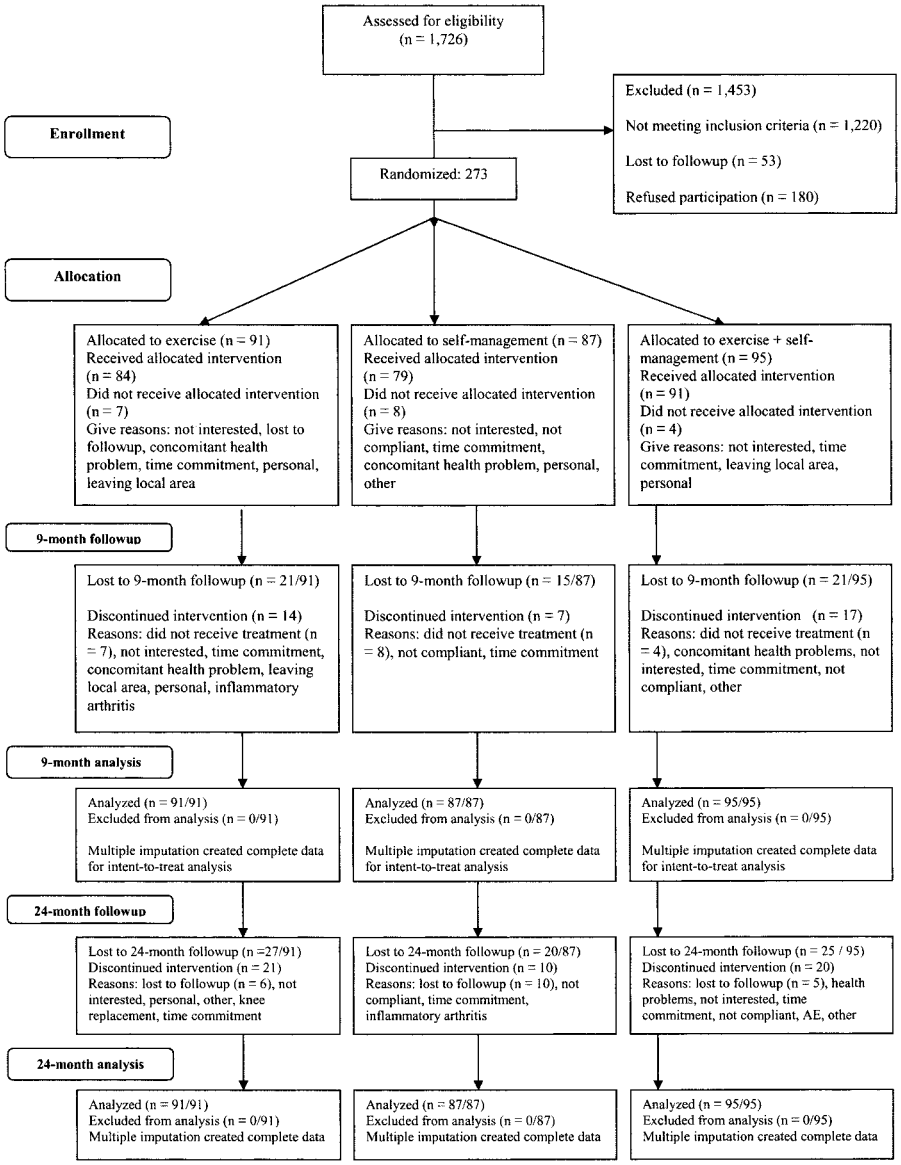

Figure 1. Consort diagram. AE = adverse event.

than the strength training or self-management groups on both outcomes). The trial was designed to randomize ~270 subjects among the intervention groups to achieve a post-attrition sample size of 60 in each group at the end of 24 months. A total sample size of 180 was projected to provide 80% power to detect a small effect size ($f^2 = 0.063$), with the alpha level set at 0.05 among the groups. Missing data were handled with a multiple-imputation procedure, imputing 5 complete data sets (23–25) to provide complete data for our intent-to-treat analyses. If the amount of missing information was negligible for the primary predictor of month, then a single randomly selected complete data set would be used for the analysis. Otherwise, all of the resulting data sets would be averaged and the missing information (γ) reported. All hypothesis tests were 2-sided.

The primary analyses consisted of linear mixed-effects regression models using the lmer procedure in the R statistical package (26). A total of 7 regression models were run: one for each dependent variable that included the 5 physical function tests (leg press, range of motion, ERGOS, get up and go, and stair climbing) and the 2 self-reported outcomes (pain and disability). Group contrasts were dummy coded a priori using self-management as the default comparison category with the combined and strength training groups. A Hochberg and Benjamini method (27) helped alleviate problems of multiple comparisons across the models.

A general set of covariates (BMI, age, sex, and arthritis severity) was specified prior to testing 2 primary predictors (effect over time measured by months in treatment and treatment group). Only 3 repeated measures were available for the physical functioning tests, so those models were restricted to linear effects. The additional repeated measures for the self-reported outcomes allowed us to test for linear and quadratic (i.e., curvilinear) effects for the month together with their interactions with the group. All of the

Table 1. Summary statistics for baseline data (study design, demographics, and relevant covariates), treatment compliance, and clinically meaningful differences in outcomes*

	Strength training	Self-management	Combined
Study design			
Randomized, no.	91	87	95
Completed (24 months), no. (%)	64 (70.3)	67 (77.0)	70 (73.7)
Demographics			
Age, years	53.3 ± 7.2	52.6 ± 6.5	51.9 ± 7.7
Women, %	80.2	74.7	76.0
White, %	92.6	96.3	86.3
College educated, %	74.1	55.9	59.1
Physical condition			
BMI, kg/m^2	27.9 ± 4.5	27.9 ± 4.1	27.4 ± 4.1
Arthritis severity (measured on a VAS)	24.0 ± 22.9	25.0 ± 24.6	23.2 ± 18.7
SF-36 physical subscale	62.3 ± 16.0	58.4 ± 17.8	61.8 ± 14.7
Mental condition			
SF-36 mental subscale	74.4 ± 15.8	67.8 ± 16.8	71.6 ± 15.9
Depression (CES-D)	7.4 ± 7.5	10.4 ± 8.2	7.8 ± 6.5
Compliance			
Phase 1			
Strength training	69.5 ± 25.2	NA	72.1 ± 22.0
Self-management	NA	74.8 ± 43.4	75.0 ± 43.3
Phase 2			
Strength training	39.5 ± 36.9	NA	44.1 ± 32.1
Self-management	NA	62.0 ± 48.5	61.6 ± 48.7
Clinically meaningful change			
Functioning, 26% change from baseline/no. (%)	64/91 (70)	56/87 (64)	63/95 (66)
Pain, 40% change from baseline/no. (%)	59/91 (65)	49/87 (56)	62/95 (65)

* Values are the mean ± SD unless otherwise indicated. No significant differences existed between the treatment groups on any of the demographic variables, compliance estimates, or clinically meaningful change frequencies. BMI = body mass index; VAS = visual analog scale; SF-36 = Short Form 36; CES-D = Center for Epidemiologic Studies Depression Scale; NA = not applicable.

models were tested via standard nested model procedures to account for error structures as well as fixed, random, and independent random effects. Finally, we calculated the percentages of participants achieving clinically relevant improvement criteria of 26% and 40% reductions in the WOMAC pain and disability scores, respectively (28).

RESULTS

The staff recruited 1,726 potential participants beginning September 2003, ~21 weeks prior to baseline testing, and continued recruitment throughout the study (December 2006). A total of 492 potential participants (29%) met the initial screening eligibility criteria and received knee radiograph examinations. Of those, 163 (33%) failed radiograph criteria and another 56 failed to enroll for other reasons, leaving 273 who were randomized to one of the 3 treatment groups (Figure 1). Following randomization, 19 participants (7%) failed to receive the assigned treatment after the run-in period due to lack of interest, noncompliance, health problems, or moving from the local area, resulting in 254 participants who received the assigned treatment. The characteristics of the randomized participants are shown in Table 1. All of the results reflect analyses of the original 273 assigned participants in an intent-to-treat analysis.

Nearly three-quarters of the assigned participants finished the trial after 2 years (201 of 273 for a 2-year completion rate of 73.6%). Retention among the groups was not significantly different (Table 1), and the demographic variables (i.e., age, sex, race, arthritis severity, pain, disability, and comorbid medical conditions) failed to predict dropout.

Treatment compliance varied somewhat by group, treatment, and project phase (Table 1). Overall compliance was higher during phase 1 (67.5%) compared with phase 2 (50.3%), with negligible differences between the groups. The self-management treatment group had higher compliance rates than any portion of the strength training group as expected because fewer opportunities existed for noncompliance with the self-management participants compared with the strength training or combined groups.

A total of 15 adverse events were definitely related to the study, 30 adverse events were possibly related to the study, and 13 adverse events were probably related to the study. These study-related adverse events consisted of increased knee pain (OA flare-up), accident/injury related to strength training, and pain/soreness from strength training. Of those, only one adverse event possibly related to the strength training intervention resulted in a withdrawal from the study (Figure 1). Here, a participant in the strength training group exacerbated a preexisting lower

Table 2. Unstandardized parameters and standard errors for the linear mixed-effects models*

Outcome	Intercept	Covariates				Predictor month	R^2_{adj}
		Body mass index	Age	Men	Arthritis VAS		
Leg press†	−0.48 (0.27)	0.03 (0.01)‡	−0.02 (0.003)‡	1.26 (0.06)‡	−0.004 (0.001)‡	0.03 (0.004)‡	0.41
Range of motion§	1.05 (0.24)‡	−0.03 (0.005)‡	−0.01 (0.003)	0.28 (0.05)‡	−0.005 (0.001)‡	0.03 (0.004)‡	0.22
ERGOS†	1.40 (0.30)‡	−0.02 (0.01)	−0.02 (0.003)‡	0.44 (0.07)‡	−0.008 (0.001)‡	0.02 (0.005)‡	0.16
Get up and go§	1.37 (0.24)‡	−0.03 (0.005)‡	−0.01 (0.003)‡	0.02 (0.05)	−0.01 (0.001)‡	0.02 (0.004)‡	0.16
Stair climbing†	1.27 (0.24)‡	−0.02 (0.005)‡	−0.01 (0.003)	0.19 (0.05)‡	−0.006 (0.001)‡	0.01 (0.004)‡	0.13
Pain§	−0.10 (0.21)	0.01 (0.004)	−0.003 (0.003)	0.12 (0.05)‡	0.01 (0.001)‡	−0.05 (0.02)‡	0.13
Disability§	−0.65 (0.21)‡	0.01 (0.004)‡	0.006 (0.003)	0.04 (0.05)	0.01 (0.001)‡	−0.04 (0.02)‡	0.12

* The unstandardized parameters shown come directly from the linear mixed-effects model results. Because treatment group was not a significant predictor, it was omitted from the table. Each parameter shows how much of a change in the outcome would be expected given a unit change in the covariate or predictor (month). VAS = visual analog scale.
† Best-fitting model specified a random intercept parameter with a fixed linear slope parameter for month.
‡ $P < 0.0001$. All other P values > 0.02.
§ Best-fitting model specified dependent random intercept and random slope parameters.

back injury. One additional adverse event possibly related to strength training was unresolved at the end of the study; however, the participant did not drop out, she ceased exercising but provided followup responses to end-study measures. Beyond these last 2 adverse events, no other study-related adverse events remained unresolved at the end of the study. Adverse events that did not result in withdrawals are not reflected in Figure 1.

The multiple imputation procedure produced 5 complete data sets for each analysis. Comparisons across the 5 complete data sets indicated that the amount of missing information was negligible (mean $\gamma < 0.00001$); parameters from each imputed data set were not significantly different, so we utilized a randomly selected imputed data set for analyses rather than averaging the parameter estimates across the 5 data sets.

All of the outcomes showed a significant change over time (Table 2), regardless of treatment assignment. The self-reported outcome measures had sufficient repeated measures to test both linear (month) and quadratic ($month^2$) parameters; only the linear parameter was significant for all of the models.

Preliminary correlations among the 7 outcomes indicated small relationships (mean $r < 0.2$) among the outcomes; therefore, we analyzed the outcomes separately for each outcome measure. Figures 2 and 3 show the changes observed by group over time for the 7 different outcomes, including the 5 objective performance tests and the 2 self-reported outcomes, respectively. The primary hypotheses were tested by the interaction between the month and the treatment assignment. None of the interactions was significant for any of the models. Furthermore, no main effect for treatment was significant either, indicating that there were no differences over time, nor were there pooled differences between the treatment groups. Table 3 documents the within-group and between-group effect sizes and 95% confidence intervals for each of the 7 outcome measures; all of the within-group effect sizes were significantly different from zero with the exception of one (the strength training group for the pain outcome). In contrast, no between-group effects were significant. Finally, the majority of the participants in all of the groups achieved clinically relevant improvements in WOMAC disability (26% criterion) and pain (40% criterion) (Table 1).

DISCUSSION

These results show that over a 24-month period, physically inactive middle-aged people with symptomatic knee OA benefited equivalently from a program of strength training, self-management, or the two combined. Those benefits were significantly larger for men compared with women, but the beneficial effects for women were still pronounced because women outnumbered men by a factor of 3 to 1. Men gained significantly more large muscle mass strength, but also tended to report more pain than women.

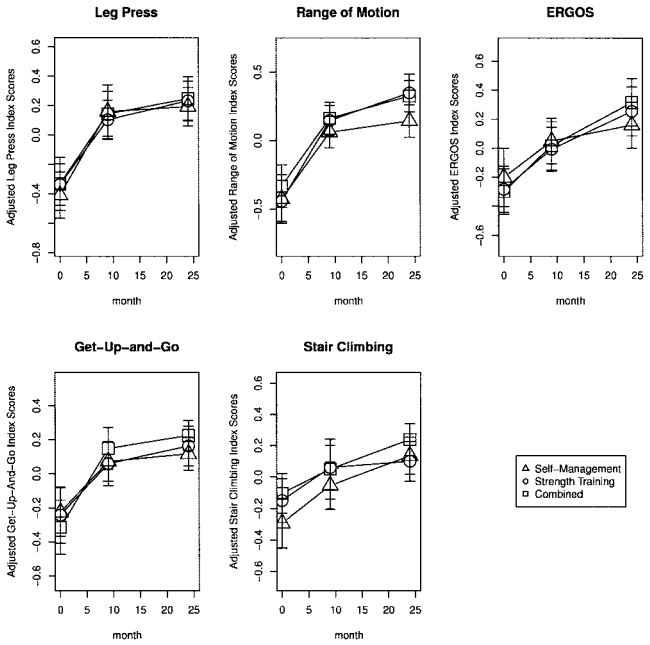

Figure 2. Three repeated measures (measured at baseline, 9 months, and 24 months) for 5 objective functional outcomes for the 3 treatment groups are shown. Error bars at each point show the 95% confidence intervals. Higher numbers for all outcomes indicate better functioning.

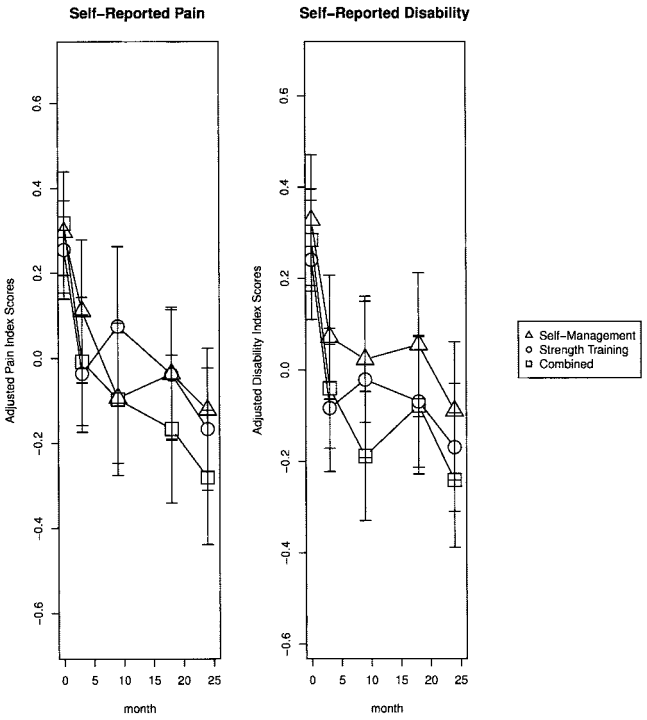

Figure 3. Five repeated measures (measured at baseline, 3 months, 9 months, 18 months, and 24 months) for self-reported pain and disability for the 3 treatment groups are shown. Error bars at each point show the 95% confidence intervals. Lower values for both outcomes indicate less pain and disability.

Therefore, both men and women benefited from these treatments. Benefits were even more evident in objective physical tests than in self-reported outcomes. Additionally, improvements in disability and pain were clinically relevant for the majority of participants across treatments, reaching 26% improvement in function and 40% improvement in pain scores (28).

The logic behind the combined treatment was that the different factors addressed in physical and psychological treatments might produce an additive effect if administered together. These results suggest otherwise. Instead, the comparison of the 3 treatment arms showed no differences, suggesting similar benefits for all 3 over a 2-year period.

No-difference findings may not be surprising given the study length. Lengthy exercise studies tend to weigh heavily on the participants and their treatment compliance wanes. These no-difference findings might indicate a regression artifact where participants regress back to lower mean functional impairment levels. Although plausible, we are persuaded otherwise because all 3 groups showed continued improvement over 24 months despite waning compliance and average within-group effect sizes in the medium to high range. Furthermore, an analysis of the pre– versus post–run-in data shows that the participants were quite healthy and pain free prior to treatment: mean scores on an 11-point pain VAS (range 0–10, where 0 = none and 10 = extreme) were approximately 5 points at pre–run-in and 3 points at post–run-in (effect size 1.66). Furthermore, our sample was younger than typical knee OA treatment samples and thus may have been much higher functioning than those in other studies. Higher functioning would mean that there was less opportunity to produce an effect. The self-reported physical functioning scores on the SF-36 compare favorably with a generally healthy sample (29), yet the 3 treatments still improved functionality. In effect, the study length and sample age might have decreased our ability to see differences among the 3 groups. Finally, the combined treatment burden may have diluted the effects of both strength training and self-management and produced no-difference results.

One implication of the negligible gains in combining treatments over either strength training or self-management alone might be that costs and patient burden would rule out the combined treatment. This implication, however, only pertains to functional outcomes, both directly measured and self-reported. Other outcomes not studied here, such as physical activity level, perceived self-efficacy of controlling treatment, or other relevant long-term outcomes, might respond more to combined treatments. At this point, improvements in these other outcomes are purely speculative and deserve further study.

Another implication is that given a relatively young OA

Table 3. Effect sizes within the groups and between the groups*

	Within-group effect sizes†			Between-group effect sizes‡		
Outcome	Combined	ST	SM	ST + SM vs. ST	ST + SM vs. SM	ST vs. SM
Leg press	0.82	0.89	0.84	0.08	0.22	0.15
Range of motion	1.04	1.16	0.79	0.06	0.36	0.29
ERGOS	0.66	0.66	0.47	−0.01	−0.01	0.00
Get up and go	0.66	0.53	0.58	0.01	0.08	0.06
Stair climbing	0.58	0.56	0.64	0.05	0.17	0.12
Pain	−0.70	−0.24	−0.59	−0.24	−0.15	0.10
Disability	−0.79	−0.43	−0.43	−0.19	−0.33	−0.11

* Effect sizes were computed using the standard Cohen's d method, where effect sizes reflect standardized (Z score) units for each outcome. The 95% confidence intervals were ±0.3 for each parameter. ST = strength training; SM = self-management.
† Based on the expected change, given the linear mixed-effects model results.
‡ Based on the observed differences between baseline and 24 months.

population, both strength training and self-management result in functional improvement. Patients unwilling or unable to exercise might still benefit from treatment that is less costly (30,31) but equally effective in producing functional gains.

Several limitations warrant mention. First, we did not assess treatment effects on articular cartilage and inflammation. Experts recognize the importance of mechanical loading for maintaining healthy cartilage (32). Furthermore, chronic exercise has been shown to reduce both local and systemic inflammatory factors (33), which play a central role in knee OA onset and progression. Second, omitting a no treatment arm eliminated a direct test of treatment effectiveness. Most middle-aged people with early knee OA symptoms may not seek treatment, and therefore, the no treatment group would be a suitable comparison. Third, potential differences in self-medication practices (e.g., if the self-management group had used more analgesics and/or nonsteroidal antiinflammatory drugs than the other groups) throughout the study could affect the between-group differences. Fourth, due to difficulties recruiting men, we were not able to perform an adequate sex-stratified analysis. Finally, the sample might have limited the effects of each treatment since the participants were highly functioning individuals at baseline.

Our results show that 2 nonpharmacologic treatments, strength training and self-management, produce gains in our unique sample of middle-aged people with knee OA. Although physical activity is linked with reduced risk for obesity, cardiovascular disease, hypertension, and diabetes mellitus (34), self-management may be a less intrusive and equally effective early treatment for knee OA. Insofar as physical function is a prerequisite to maintaining health-protective levels of physical activity, our results suggest there may be broad health benefits from strength training and self-management for patients with early OA. Health care providers may confidently recommend self-management and strength training for their OA patients, constrained only by availability, costs, burden, or preference.

AUTHOR CONTRIBUTIONS

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be submitted for publication. Dr. McKnight had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study conception and design. McKnight, Going, Villanueva, Cornett, Zautra.

Acquisition of data. Kasle, Villanueva, Cornett, Farr, Wright, Streeter, Zautra.

Analysis and interpretation of data. McKnight, Kasle, Going, Villanueva, Zautra.

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