The Effect of Dynamic Versus Isometric Resistance Training on Pain and Functioning Among Adults With Osteoarthritis of the Knee

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ABSTRACT. Topp R, Woolley S, Hornyak J III, Khuder S, Kahaleh B. The effect of dynamic versus isometric resistance training on pain and functioning among adults with osteoarthritis of the knee. Arch Phys Med Rehabil 2002;83:1187-95.

Objective: To compare 16 weeks of isometric versus dynamic resistance training versus a control on knee pain and functioning among patients with knee osteoarthritis (OA).

Design: Randomized clinical trial.

Setting: Outpatient setting.

Participants: A total of 102 volunteer subjects with OA of the knee randomized to isometric (n=32) and dynamic (n=35) resistance training groups or a control (n=35).

Interventions: Strength exercises for the legs, 3 times weekly for 16 weeks. Dynamic group: exercises across a functional range of motion; isometric: exercises at discrete joint angles.

Main Outcome Measures: The time to descend and ascend a flight of 27 stairs and to get down and up off of the floor. Knee pain was assessed immediately after each functional task. The Western Ontario and McMaster Universities Osteoarthritis Index was used to assess perceived pain, stiffness, and functional ability.

Results: In the isometric group, time to perform all 4 functional tasks decreased ($P<.05$) by 16% to 23%. In the dynamic group, time to descend and ascend stairs decreased by 13% to 17%. Both groups decreased knee pain while performing the functional tasks by 28% to 58%. Other measures of pain and functioning were significantly and favorably affected in the training groups. The improvements in the 2 training groups as a result of their respective therapies were not significantly different. The control group did not change over the duration of the study.

Conclusion: Dynamic or isometric resistance training improves functional ability and reduces knee joint pain of patients with knee OA.

Key Words: Exercise; Knee; Osteoarthritis; Pain; Rehabilitation.

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OSTEOARTHRITIS (OA) IS A COMMON, progressive health problem among adults.[1] It is estimated that 80% of all adults at or over the age of 65 years exhibit radiographic evidence of OA.[2,3] A majority have OA-related pain, which is thought to contribute to 10% to 25% of all visits to primary care physicians[4,5] and is the second most common cause of disability among older adults.[6,7] When symptoms of the disease affect the knee, as in 10% of all adults, it results in a limited ability to use stairs, arise from a chair, stand comfortably, walk, and complete activities of daily living (ADLs).[8,9] Ettinger et al[10] reported that 50% to 71% of their sample with knee OA had difficulty ambulating and 44% to 67% had difficulty transferring. Pain in the affected joint is the most common symptom of OA and contributes to significant declines in functional ability, including getting up off the floor and going up and down stairs.[11,12] Investigators have observed declines in leg strength, particularly in the quadriceps of both the knees affected with OA[13] as well as the quadriceps of the contralateral knee that is asymptotic for OA. The relationship between joint pain and declines in muscle strength are beginning to be recognized as more complex than simply disuse because of joint pain contributing to muscle atrophy and muscle weakness surrounding joint.[14,15] Investigators[15,16] have speculated that progression of knee OA may be a result of declines in quadriceps motor and sensory functions. Regardless of the true pathologic changes occurring with knee OA, declines in ADLs or in functional abilities, measured objectively and by self-report, have consistently been associated with increasing levels of pain and declines in quadriceps strength.[14,17]

Numerous previous investigators have found that the strength declines among older adults can be reversed through regular resistance training,[18-22] even among frail older adults.[23] Previous investigators[24-26] have been able to slow or reverse these negative outcomes of OA in adults through various exercise interventions, including resistance training. Deyle et al[27] reported knee OA patients who participated in 8 weeks of a leg stretching and strengthening program significantly improved their walking speed and their perceived levels of functioning. Similarly, O'Reilly et al[28] reported that 6 months of daily low-intensity resistance training exercises decreased the pain during walking and stair climbing by 19% to 21%, respectively, among patients with OA of the knee. Petrella[29] and van Baar et al[30] reviewed 33 studies and reported that exercise treatment had small to moderate effects on joint pain, small effects on functional outcome measures, and more moderate effects on self-perceived measures of functioning. These investigators indicated that diverse exercise interventions appear to have a beneficial effect on OA patients and concluded by stating future investigators may wish to examine changes in functional outcome measures relevant to OA patients as a result of specific exercise interventions.

Interventions that use either isometric or dynamic resistance training positively impact the symptoms of OA.[31-36] A significant limitation of the studies on isometric resistance training is

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that the training took place at discrete joint angles, which may explain the limited improvements in functional ability.[31,33,37,38] Although functional ability requires movement of the joint over a functional range, isometric resistance training improves muscle strength only at the joint angle at which the training takes place. This specificity of training principle may limit how much isometric training can affect performance of functional tasks that feature joint movement beyond the joint angle prescribed in the isometric training. Conversely, a possible advantage of isometric training may be that it does not stress the joint over a functional range of motion (ROM). Reduced joint movement may result in less pain during and after the resistance training. In contrast, dynamic resistance training in non-OA subjects improves the strength of the trained muscle over the entire ROM at which resistance training took place. It has been reported that dynamic resistance training correlates with improved knee strength,[39] increased neuromuscular performance,[40] and improved performance on select functional tasks,[26] but not over the improvements observed in a control group[41] among OA subjects. Although dynamic resistance training improves strength and functioning over the training ROM, the joint is being loaded while it is moved, which may result in pain among OA patients.

Previous investigators[42,43] have reported that, by using elastic resistance devices, older adults can gain strength similar to the gains achieved by more traditional modes of resistance training over a period of 14 to 16 weeks of training. Jette et al[44] reported that after 3 and 6 months of resistance training with elastic bands of varying resistance, lower-extremity strength improved 6% to 12%, tandem gait improved 20%, and subjects reported a 15% to 18% decrease in disability. Krebs et al[45] reported that elastic resistance training among elders with functional limitations produced moderate gains in strength along with improvements in gait characteristics. Finally, Damush and Damush[46] reported that an 8-week resistance-training program, which used elastic bands as the mode of resistance, resulted in 14% to 26% improvements in strength among community-dwelling older women. It might therefore be reasonable to expect that OA patients who undergo dynamic resistance training using Thera-Band® elastic bands[a] will show declines in knee pain and improvements in functional ability. To date, no study has compared the effects of dynamic versus isometric resistance training on knee pain and functional ability of adults with OA of the knee. Thus, the purpose of the present study was to compare differences in knee pain and functional ability among adults with knee OA to test the efficacy of 16 weeks of isometric versus dynamic resistance training with elastic bands versus a control condition. This purpose generated 2 research questions: (1) Does 16 weeks of dynamic or isometric resistance training have differential effects on perceived knee joint pain, stiffness, and functional ability compared with a control condition among patients with OA of the knee?; and (2) Does 16 weeks of dynamic or isometric resistance training have differential effects on performance of functional tasks compared with a control condition among patients with OA of the knee?

METHODS

Sample

One hundred two community-dwelling women (n=74, 72.5%) and men (n=28, 27.5%) previously diagnosed with knee OA volunteered and participated in the present study. Subjects were recruited from physician offices, local senior centers, and local arthritis support groups. Subjects were included if, during an initial telephone interview, they reported a moderate degree of knee pain because of OA as evidenced by a score of 5 or greater on the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain subscale. A physician validated the knee pain and diagnosis of OA of the knee using previously established criteria[47] during a history and physical examination. Potential subjects were excluded if they showed any contraindications for exercise, including a history of uncontrolled angina, cardiomyopathy severe enough to compromise cardiac functioning, electrolyte or metabolic disturbances, disabilities that prohibited resistance training of the lower extremities, or if they were currently taking nitrates, digitalis, or phenothiazine. Individuals were also excluded if they were currently participating in an organized exercise program or exercised more than 1 hour per week.

Outcome Measures

Subjects who were not excluded during the initial telephone interview were invited to complete a background and demographic questionnaire and underwent a history and physical examination, including an electrocardiogram. Subjects were excluded from further participation if their history, physical examination, or electrocardiogram indicated that they might have difficulty with the testing procedures or if they were found to have knee pain attributable to a cause other than OA, including fibromyalgia, bursitis, tendonitis, a tear of the articular cartilage as evidence by a positive McMurray sign, or underlying arthropathy of the knee or pain in the lower back, hips, or ankles. Subjects who were eligible for the study completed 3 categories of assessments before being randomized into treatment groups. Subjects again completed these assessments after 16 weeks of participation in their respective treatment group. The first assessment included the subject reporting background information on demographics (collected only at baseline) and use of medications to manage their knee pain. The second assessment included paper and pencil instruments that solicited the subject's perceived pain, stiffness, and functional ability. Finally, pain and functional ability were assessed while each subject performed 4 functional tasks.

Background information included demographic and medication information. Demographic characteristics of the sample included age, weight, gender, race, and number of previously diagnosed chronic conditions. At both the baseline and 16-week retest, all subjects were requested to submit a list of their prescription and nonprescription medications that they consumed on average over the previous 2 weeks to manage their knee OA. The drug name, dose, and frequency for each medication were recorded. These medications included acetylated and nonacetylated salicylates, other nonsteroidal anti-inflammatory drugs (NSAIDs), narcotic and nonnarcotic analgesics, histamine$_2$-receptor antagonists, misoprostol, and glucosamine-chondroitin sulphate. These medication data were then translated into medication dose effect for each medication for each subject. Medication dose effect was defined as the necessary amount of medication to achieve a therapeutic effect for the individual patient divided by the maximum recommended dosage. Griffin et al[48] described calculating medication dose effect for a specific medication an individual is taking by dividing total prescribed daily dose (mg/d) of the individual medication by the daily referenced dose referred to in the *Physicians' Desk Reference*.[49] For the present study, the referenced dose was the maximum recommended daily dose of the medication cited in the *Physicians' Desk Reference*. If the subject reported taking multiple medications to manage their knee pain, a dose effect was calculated for each medication and then these ratios were summed to arrive at a total dose effect needed to manage their knee pain. Griffin et al[48] have reported this method of stan-

Individual daily amount comsumed=500mg every 12h (1000mg/d)

Maximum daily dose referenced in the PDR=2600mg/d

Dose-effect of acetaminophen for this individual=1000mg/2600mg=.3846

Fig 1. Example of calculating dose-effect of acetaminophen to treat knee pain. Abbreviation: PDR, *Physician's Desk Reference*.

dardizing NSAIDs to be a valid predictor of chronic disease in the elderly. These dose-effect ratios were compared between the baseline and 16-week testing times to evaluate whether the subjects were taking differing amounts of different medications between the 2 testing times to manage their knee pain. An example of how a medication's dose effect was calculated is stated in figure 1.

Perceived pain, stiffness, and functional ability were assessed by means of the WOMAC. The WOMAC is a multidimensional, disease-specific, self-administered health status instrument for patients with OA of the hip and knee.[50] It is composed of the 3 subscales of perceived pain, stiffness, and functional ability. The individual completing the instrument rates his/her perceived pain, joint stiffness, and functional ability on a 5-point (none, slight, moderate, severe, extreme) Likert scale, which is scored from 0 to 4. The scores for each dimension were determined by summing the items contributing to each of the subscores. Higher scores on these subscales indicated higher degrees of joint pain, joint stiffness, and functional limitations. Bellamy et al[51] reported acceptable reliability coefficients (Cronbach $\alpha \geq .85$) for all of the WOMAC subscales. Construct validity of the WOMAC was considered acceptable compared with other instruments that measured pain, stiffness, physical capacity, and joint tenderness. The subscores of joint pain, joint stiffness, and functional limitations subscales obtained from the WOMAC were used in the statistical analyses.

Knee pain and performance of functional tasks included the time to perform an individual functional task and the subject's report of knee pain while performing the functional task. These tasks were selected as measures of functional ability because they have been cited as representing a significant functional challenge to OA patients.[52] These tasks included getting down to and up off the floor and ascending and descending a set of 27 stairs. These protocols have an acceptable test-retest reliability (r range=.75–.88) over a 7-day duration, whereas construct validity was established by correlating ability to perform these functional tasks with measures of quadriceps strength (r range=.34–.45).[53] The outcome of time to perform these tasks was selected rather than biomechanical measures (eg, joint velocity, joint angle, joint impact) because it was believed to be more applicable to the individual's general level of functionality. We hypothesized that the time to perform the studied task would be directly proportional to how frequently the individual performed it while performing his/her usual ADLs. Under this hypothesis, we assumed that subjects who required less time to complete a task may in fact more frequently engage in that task or similar tasks during their usual ADLs.

Getting down to and up off the floor. Subjects were asked to start from a standing position and to transfer unsupported to a supine position on the floor with their head and hands laying flat on the floor. During the task of getting up off the floor, the subject arose unaided from a supine position to an upright standing position. The timing of each task began with the subject's first movements. Subjects were instructed to perform the task as quickly and safely as possible. The time taken to complete each task was measured to 1/100th of a second by using a stopwatch. Each task was performed up to 3 times, and the fastest time for each task was used in the statistical analysis.

Descending and ascending stairs. Each subject was asked to descend and then ascend a flight of twenty-seven 15.24-cm steps. The subject started the task standing facing the stairs, with hands at sides. Timing began with the subject's first movement. Subjects were told to descend and then ascend the stairs as quickly and as safely as possible; the time taken to complete the task was measured by using a stopwatch. Subjects were allowed to use the handrails if needed. Subjects completed each trial up to 3 times and the fastest time recorded for ascent and descent was used in the analysis. The subjects were allowed to rest 15 to 30 seconds between each trial.

Pain while performing the functional task was operationalized by having the subject rate his/her knee pain in both the right and left knee on an 8-cm horizontal visual analog scale ranging from no pain (0) to the worst pain possible (8). The knee pain while performing the functional task was the sum of the 2 knee pain ratings with higher scores indicating higher degrees of pain while performing the specific functional task.

Interventions

After baseline testing, subjects were randomly assigned to 1 of 3 treatment groups; dynamic resistance training (dynamic group), isometric resistance training (isometric group), or a no intervention group (control group). Subjects assigned to the 2 resistance training groups began their respective treatments, documenting their exercise compliance on the first day of the week after their baseline testing. Both resistance-training interventions trained the same 6 muscle groups of the legs (ie, ankle plantar- and dorsiflexors, knee extensors and flexors, hip extensors and flexors). All resistance training occurred bilaterally, with both resistance-training interventions exposing the subjects to the same duration of muscle tension and rest during each exercise session. Both interventions of resistance training included the same scheduled increases in repetitions and sets over the 16-week training protocol.

The dynamic resistance-training group was given a strength-training booklet, which explained 6 resistance-training exercises performed by using Thera-Band elastic bands. This dynamic resistance-training booklet was based on a previous resistance-training protocol that used Thera-Band elastic bands and was found to result in significant improvements in leg strength after 12 weeks of training.[54] These exercises have been previously described in detail.[55] The booklet described the warm-up, strength-training, and cooldown components of a session of resistance training. Resistance training with Thera-Band elastic bands as the mode of resistance was selected for 2 reasons. First, previous unpublished work indicated that the minimum weight on standard universal weight training machines was in excess of some of the subjects' initial strength capacity; also, an unpublished pilot study among a sample of OA subjects indicated that the weight increments on the universal weight machines were too great to yield a smooth progression of training. The second reason Thera-Band elastic bands were selected is that this mode of resistance training permitted subjects to continue training if they were unable to attend the supervised dynamic resistance-training classes. Dynamic resistance training with elastic bands also provided progressive resistance to the muscle group over a functional ROM. Subjects were requested to complete the 6 muscle-strengthening exercises bilaterally 3 times weekly. Two of these weekly exercise sessions took place unsupervised in the subject's home, and 1 session each week was under the super-

vision of the project staff in an organized class. Subjects recorded their compliance with this prescribed exercise in an exercise log. The exercise log was checked by the exercise leader after each supervised session of resistance training.

Initially, a session of dynamic resistance training included a 5-minute warm-up, 30-minute dynamic resistance training, and 5-minute cooldown. The warm-up consisted of mild unweighted leg movements to increase blood flow to the leg muscles. After the warm-up, subjects completed the 6 dynamic resistance-training exercises, which were designed to develop the ankle dorsi- and plantarflexors, knee flexors and extensors, and hip flexors. During training weeks 1 and 2, each subject performed 1 set of 8 repetitions of each exercise using a band of sufficient resistance to result in a rating of perceived exertion of mild fatigue after 8 repetitions. Subjects increased the number of repetitions and/or sets of repetitions every week in a scheduled progression of training outlined in their exercise booklets. Progression of training continued until during weeks 9 to 16 each subject performed 3 sets of 12 repetitions of each exercise with a Thera-Band elastic band of sufficient thickness to produce a perceived exertion rating of moderate fatigue at the end of each set of 12 repetitions with a 2-minute rest between sets (approximately 50min). The cooldown consisted of 5 minutes of stretching exercises.

The isometric resistance-training group was given a strength-training booklet that explained the 6 resistance-training exercises by using standard isometric training techniques.[56] These techniques required the individual to generate tension in the muscle without changing the joint angle. Subjects generated this muscle tension by using maximum-resistance Thera-Band elastic bands, which they were unable to stretch during the exercise. Subjects performed the 6 isometric resistance-training exercises bilaterally 3 times a week while positioning the targeted muscle and joint at a predetermined joint angle. After positioning the joint to the prescribed angle, the subject generated tension against the Thera-Band elastic bands in the muscle group for 3 to 5 seconds without moving the joint angle. Training joint angles included 0° of dorsi- and plantarflexion when performing ankle dorsi- and plantarflexion of the ankle, 10° of knee flexion when performing knee flexion and extension, and 10° of hip flexion and 10° of hip extension when performing the 2 hip resistance training exercises. During training weeks 1 and 2, each subject performed 1 set of 8 repetitions while producing mild or submaximum muscle tension during the exercise. After these first 2 weeks, each subject was told to complete each isometric repetition while producing maximum muscle tension for 3 to 5 seconds. This intensity of training was designed to produce a moderate degree of muscle fatigue at the end of the final repetition of the set for each exercise. Subjects increased the number of repetitions and/or sets of repetitions every week in a scheduled progression of training outlined in their exercise booklets. Progression of training continued until during weeks 9 to 16 each subject performed 3 sets of 12 repetitions of each exercise with a 2-minute rest between sets (approximately 50min). The cooldown consisted of 5 minutes of stretching exercises. Two of these weekly exercise sessions took place unsupervised in the subject's home, and 1 session each week was under the supervision of the project staff in an organized class. Subjects recorded their compliance with this prescribed exercise in an exercise log. The exercise log was checked by the exercise leader after each supervised session of resistance training.

Control group subjects were not given any intervention between baseline testing and the 16-week posttest. The decision to develop a no-intervention control group was based on the possible positive effect that even minor amounts of placebo-type activity interventions may have on severely detrained older adults. As an incentive to remain in the study all control group subjects were offered 2 weeks of either isometric or dynamic resistance training after their 16-week posttest. Controls were told not to change the usual amount of activity they engaged in before beginning the project.

RESULTS

Analyses of the data were conducted in 2 steps. The first step was to examine the sample at baseline for group differences in potentially confounding demographic or background variables. In this first step we also determined differences within or between the treatment groups in medication dose effect over the duration of the study. Table 1 presents comparisons between the continuous and discrete demographic variables collected from the sample at baseline. These analyses indicated no significant differences between the groups on the variables of age (mean, 63.3y), weight (mean, 196.7lb), and number of previously diagnosed chronic conditions (mean, 2.28 conditions). All groups indicated a similar distribution of women to men of approximately 74% women and 28% men. Chi-square analyses appeared to indicate that the control group included a higher percentage of blacks (20%) than either the dynamic group (11%) or the isometric group (6%). Table 2 shows the results of the repeated-measures analysis of variance (ANOVA) of medication dose effect within and between the groups over the 2 data collection points (baseline, 16-wk retest). These analyses revealed no significant change in medication dose effect within or between the treatment groups over the duration of the study. The subjects had an average medi-

Table 1: Demographic Characteristics of the Sample

Variable	Control (n=35) Mean ± SEM	Dynamic (n=35) Mean ± SEM	Isometric (n=32) Mean ± SEM	Significance
Age (y)	60.94±1.82	65.57±1.82	63.53±1.90	F=1.62, *P*=.20
Weight (lb)	195.31±7.14	199.49±7.13	195.19±7.46	F=0.12, *P*=.89
No. of previously diagnosed chronic diseases	2.37±.20	2.26±.20	2.22±.21	F=0.15, *P*=.86
Gender, n (%)				χ^2=1.77, *P*=.41
Male	7 (20)	10 (29)	11 (34)	
Female	28 (80)	25 (71)	21 (66)	
Race				χ^2=118.30, *P*=.00
White	28 (80)	31 (89)	30 (94)	
Black	7 (20)	4 (11)	2 (6.3)	

Abbreviation: SEM, standard error of the mean.

Table 2: Medication Dose Effect to Manage Knee Pain, Isokinetic, and Isometric Knee Extension by Group and Time

Variable	Group	n	Pretest Mean	Pretest SEM	Posttest Mean	Posttest SEM	Change (%)	Significance
Medication dose effect to manage knee pain	Control	35	.55	.10	.49	.09	.06 (−11)	NS
	Dynamic	35	.58	.10	.52	.09	.06 (−10)	
	Isometric	32	.62	.10	.53	.10	.09 (−15)	

Abbreviation: NS, not significant.

cation dose effect at the beginning of the study of .58 and ended the study with a nonsignificant decrease in medication dose effect of .51 (−12%).

The second step of the analysis addressed the study research questions. Repeated-measures ANOVA was employed to determine the effect(s) of group, time, and the interaction of group by time on the pain and functional ability variables. Significant main or interaction effects ($P<.05$) were then further examined by calculating Bonferroni minimal significant difference ($BMSD=Bon_{\alpha=.05}\sqrt{[MSE/n_1]+[MSE/n_2]}$) between the means. Any 2 means that differed by more than the BMSD were determined to be significantly different at the P less than .05 level of significance. Table 3 presents the means, standard error of the means, and significance for group, time, and/or interaction for the perceived pain, stiffness, and functional limitations subscales of the WOMAC. Included in the significance column of this table is the BMSD value for the specific variable. This table indicates that the WOMAC stiffness subscale did not significantly change within or between any of the groups over the duration of the study. Self-reports of functional limitations declined significantly on the WOMAC in both dynamic groups but remained unchanged in the isometric and control groups. Both resistance-training groups reported similar significant declines in pain on the WOMAC: these changes, in these measures over time when compared between the groups, did not exceed the BMSD.

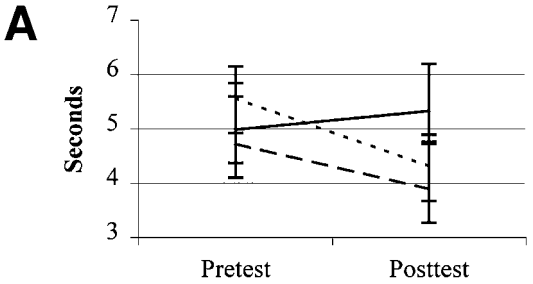
Both resistance-training groups exhibited similar significant declines in knee pain and in time to perform functional tasks while the control group remained unchanged over the duration of the study. Figures 2 through 5 present data along with means by group and time and changes in means and percentage change. Significant group, time, and interaction effects indicated by the repeated-measures ANOVA, and the BMSD calculated for these main effects are also presented in these figures. The control group did not change on any measure over the duration of the study. Figure 2A indicates a significant time effect. Only the isometric group significantly decreased the time to get down to the floor (−1.25s) by greater than the BMSD of −1.09 seconds. This decrease in time did not differ from the nonsignificant decrease in time to perform the task exhibited by the dynamic group. Similarly, only the isometric group significantly decreased the time to get up off of the floor (−1.89s) beyond the BMSD (−1.60) over the duration of the study. The dynamic group subjects showed a nonsignificant trend toward decreasing their times, whereas the control group participants did not appear to change from their baseline levels (fig 2B). Figures 3A and B show that both the dynamic and isometric groups achieved declines in their time to ascend and descend stairs beyond their respective BMSD. Comparisons between these within-group changes did exceed the respective BMSD. Thus, both the isometric and dynamic groups had similar significant decreases in their time to ascend and descend the stairs, whereas the control group did not significantly change in the performance of these functional tasks over the duration of the study.

Regarding pain while performing the 4 functional tasks, the 2 treatment groups showed a significant time or group by time interaction effect, whereas the control group reported knee pain to be unchanged during these functional tasks over the duration of the study. Figures 4 and 5 show that, over the duration of the study, both treatment groups had a significant decline in knee pain for all 4 functional tasks. Comparisons between the changes within the training groups did not exceed the BMSD for these outcome variables, and thus the declines in pain over the duration of the study were similar within each of the training groups. The dynamic group reported declines in knee pain while performing the functional tasks ranging from a decline of 58% while getting up from the floor to a 28% decline in knee pain while going up the stairs. The isometric group's pain decline ranged from a decline of 56% while getting down to the floor to a decline of 41% while descending the stairs.

Table 3: Self-Reported Measures of Pain and Functioning by Time and Group

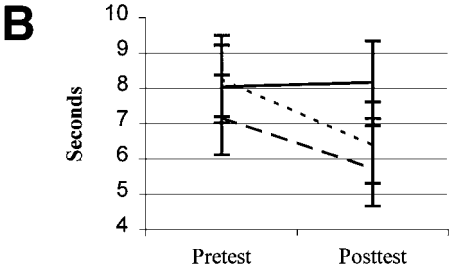
Variable	Group	Pretest Mean	Pretest SEM	Posttest Mean	Posttest SEM	Change (%)	Significance
WOMAC stiffness scale	Control	5.23	.27	5.50	.26	.27 (5)	NS
	Dynamic	5.51	.27	5.04	2.7	−.47 (−8)	
	Isometric	5.13	.29	5.03	.28	−.10 (−2)	
WOMAC functional limitations scale	Control	38.87	1.85	39.70	1.83	.17 (+2)	Signif time effect
	Dynamic*	41.09	1.85	35.30	1.83	−5.79 (−14)	$P<.05$
	Isometric	38.13	1.93	35.97	1.91	−2.16 (−6)	BMSD=3.41*
WOMAC pain scale	Control	10.75	.54	10.77	.54	.02 (0)	Signif test effect
	Dynamic*	12.40	.54	10.71	.53	−1.69 (−14)	$P<.05$
	Isometric*	11.75	.57	10.38	.56	−1.37 (−12)	BMSD=1.28*

NOTE. Control: n=35; dynamic: n=35; isometric: n=32.
Abbreviation: Signif, significant.
* $BMSD=Bon_{\alpha=.05}\sqrt{(MSE/n_1)+(MSE/n_2)}$.



	n	Pretest Mean	Pretest SEM	Posttest Mean	Posttest SEM	Change (%)
Control	35	4.98	.86	5.33	.61	.35 (7)
Dynamic	35	4.72	.87	3.89	.62	−.83 (−18)
Isometric*	32	5.56	.58	4.31	.64	−1.25 (−22)

* Significant time effect $P<.05$, BMSD=1.09s.



	n	Pretest Mean	Pretest SEM	Posttest Mean	Posttest SEM	Change (%)
Control	35	8.04	1.18	8.16	1.02	.12 (+2)
Dynamic	35	7.16	1.22	5.71	1.05	−.83 (−12)
Isometric*	32	8.26	1.24	6.37	1.06	−1.25 (−15)

* Significant time effect $P<.05$, BMSD=1.60s.

Fig 2. (A) Time to get down to the floor. (B) Time to get up off of the floor. Legend: ——, control; – – –, dynamic; - - - - -, isometric.

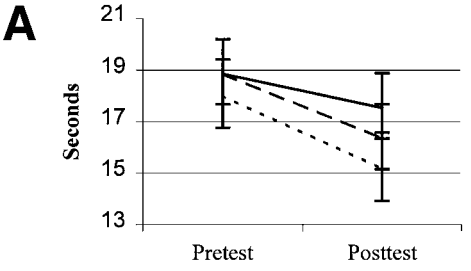
DISCUSSION

These findings answered the study's 2 research questions. Both dynamic and isometric resistance training reduced perceived knee joint pain and had no effect on perceived joint stiffness. Only the dynamic training reduced perceived functional limitations, and the control group did not change their measures on any of the outcome variables over the duration of the study.

The findings are consistent with previous investigators who have reported that exercise can reduce pain and increase the perceived and actual functional abilities of OA patients. The results of the interventions tested in the present study appear to have a greater percentage impact on improving actual functional measures and reducing pain during the performance of these functional activities than previous exercise interventions. The Fitness Arthritis and Seniors Trial[26] reported a modest 8% to 10% improvement in pain and functioning scores as a result of 18 months of aerobic or resistance exercise among their sample of knee OA patients. This modest, although significant, effect of a long-term exercise program, which included resistance training, was also reported by Rogind et al[57] who found a 20% reduction in pain and a 10% to 15% decrease in time to complete various functional tasks including stair climbing. Even the previously cited reviews[29,30] of the literature indicated that exercise seems to have a small to moderate effect on joint pain and functional outcome measures with a more moderate effect on self-perceived measures of functioning.

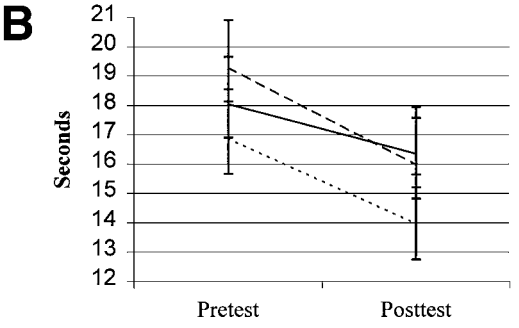
Our findings suggest that the present study's exercise interventions reduced pain and increased functional ability similarly or to a greater extent than the previously studied interventions. There may be a number of explanations for this finding. First, the present interventions were primarily resistance training and may have required a higher intensity of training than the previous studies in the area. For example, the training volume prescribed to the dynamic group to increase leg extension strength included 36 squats into and out of a chair against resistance. Similarly, the isometric group performed 36 maximal isometric muscle contractions of the quadriceps each held for 3 to 5 seconds.

In addition to the favorable gains, the exercise interventions produced over those reported by previous investigators, the present results also suggest that isometric training may be better than dynamic training for improving times in performing functional tasks. There are 2 possible explanations for this observation. First, although efforts were made to expose the 2



	n	Pretest Mean	Pretest SEM	Posttest Mean	Posttest SEM	Change (%)
Control	35	18.85	1.35	17.53	1.19	1.32 (−6)
Dynamic*	35	18.85	1.35	16.33	1.19	2.52 (−13)
Isometric*	32	17.99	1.42	15.15	1.24	2.84 (−16)

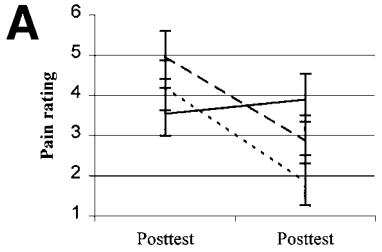
* Significant time effect $P<.05$, BMSD=1.79s.



	n	Pretest Mean	Pretest SEM	Posttest Mean	Posttest SEM	Change (%)
Control	35	18.04	1.61	16.34	1.15	−1.61(−9)
Dynamic*	35	19.29	1.61	15.96	1.15	−3.33 (−17)
Isometric*	32	16.86	1.69	13.95	1.21	−2.91 (−17)

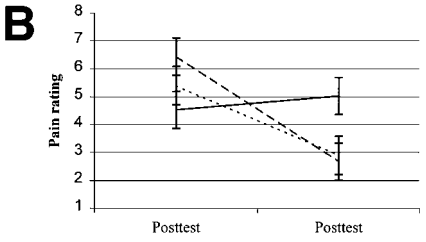
* Significant time effect $P<.05$, BMSD=2.19s.

Fig 3. (A) Time to go up the stairs. (B) Time to go down the stairs. Legend: ——, control; – – –, dynamic; - - - - -, isometric.



	n	Pretest Mean	Pretest SEM	Posttest Mean	Posttest SEM	Change (%)
Control*	35	3.54	0.64	3.89	0.55	.44 (10)
Dynamic*	35	4.96	0.64	2.86	0.56	−2.10 (−42)
Isometric*	32	4.20	0.67	1.84	0.58	−2.36 (−56)

* Significant group by time interaction effect $P<.05$, BMSD=1.80



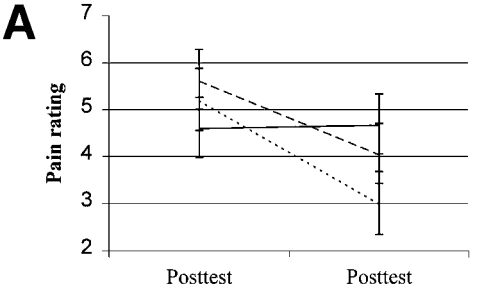
	n	Pretest Mean	Pretest SEM	Posttest Mean	Posttest SEM	Change (%)
Control*	35	4.53	0.66	5.03	0.67	.50 (11)
Dynamic*	35	6.44	0.66	2.67	0.67	−3.77 (−58)
Isometric*	32	5.39	0.69	2.89	0.68	−2.5 (−46)

* Significant group by time interaction effect $P<.05$, BMSD=1.63

Fig 4. (A) Pain while getting down to the floor. (B) Pain while getting up from the floor. Legend: ——, control; – – –, dynamic; - - - - -, isometric.

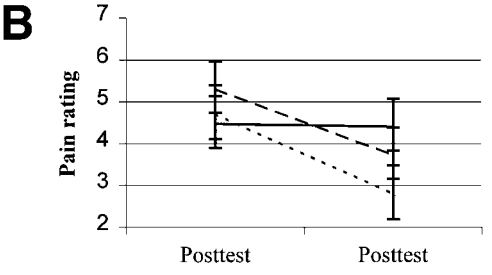
exercise intervention groups to the same duration and progression of resistance training, the isometric training may have resulted in a higher intensity of training. This hypothesis is supported by the fact that the isometric subjects were told to hold a maximum isometric contraction for each repetition of the exercise, which results in a moderate level of fatigue after the final repetition of the exercise set. The dynamic group, on the other hand, was instructed to complete the training with a Thera-Band elastic band that produced a moderate degree of fatigue after the final repetition of the exercise set. This difference in training may have exposed the isometric group to a higher intensity of training. A second explanation for this observation may be the nature of the functional tasks: perhaps they did not truly challenge the subjects over a wide range of joint motion. Ascending and descending the stairs required our dynamic group to move through a ROM for the hip (0°–30°), knee (0°–30°), and ankle (0°–10°), which was similar to the joint angle at which the isometric group trained. On observation, all subjects seemed to move through these same limited ROMs when getting down to and up from the floor. This observation is consistent with the similarity in stiffness scores within the groups over the duration of the study. The functional tasks selected as outcomes for the present study may have required the subjects to move over a limited functional ROM rather require them to move over a broader anatomic ROM. The dynamic resistance-training group might have had greater gains then the isometric group if the functional tasks had challenged the subjects to move over a broad ROM. Future investigators may wish to incorporate more challenging functional tasks into their study design or to examine modifications in the biomechanics that knee OA patients use to avoid moving their lower-extremity joints over a broad ROM.

The mechanisms through which these reductions in pain and improvements in functioning are realized by way of resistance training continues to be controversial. Several investigators[14,16,58] have reported declines in the sensorimotor function of the quadriceps (proprioception) among knee OA patients. This decline may be a primary factor contributing to the development and progression of knee OA.[59] If proprioception is impaired, the timing of the eccentric contraction of the quadriceps during weight-bearing activities will be clumsy, thus resulting in higher impact and impulsive loads being transmitted through the joint.[60] These higher loads being transmitted through the knee joint will lead to microtrauma to the articular cartilage and/or the subchondral bone, which are characteristics of knee OA.[61] A hypothesized outcome of resistance training of the leg is an increased sensitivity in the sensorimotor structures of the quadriceps including the muscle spindles and Golgi tendons.[62] Resistance training has been shown to increase the α-motor discharge or tone of the muscles trained[63] even among



	n	Pretest Mean	Pretest SEM	Posttest Mean	Posttest SEM	Change (%)
Control†	35	4.59	0.67	4.66	0.61	.07 (2)
Dynamic*	35	5.61	0.67	4.03	0.61	−1.58 (−28)
Isometric*†	32	5.19	0.69	2.98	0.64	-2.21 (-43)

* Significant time effect $P<.05$, BMSD=1.36.
† Significant group by time interaction effect $P<.05$, BMSD=1.60.



	n	Pretest Mean	Pretest SEM	Posttest Mean	Posttest SEM	Change (%)
Control	35	4.47	0.66	4.40	0.57	−.07 (−2)
Dynamic*	35	5.30	0.66	3.71	0.57	−1.59 (−30)
Isometric*	32	4.70	0.69	2.78	0.60	−1.92 (−41)

* Significant time effect $P<.05$, BMSD=1.37.

Fig 5. (A) Pain while going up stairs. (B) Pain while going down stairs. Legend: ——, control; – – –, dynamic; - - - - -, isometric.

older adults.[64] This α-motoneuron activity is reciprocally influenced by muscle spindles and Golgi complexes within the muscle. Thus, regular resistance training may attenuate the impact and impulsive loads through the knee joint, not by only increasing the strength of the muscles surrounding the knee but also by increasing the sensitivity and coordination of the proprioceptors within the quadriceps muscle during walking and other weight-bearing activities.

The findings of this study must be interpreted cautiously for a number of reasons. The sample consisted of a self-selected sample who volunteered for an exercise intervention study and may have had preconceived positive expectations regarding the benefits of the exercise intervention. These positive expectations of the exercise intervention may have resulted in a Hawthorne expectation effect among the intervention group and a negative expectation effect among the control subjects. The findings indicate a trend that all of the subjects reduced their consumption of medications to manage their knee pain over the duration of the study. Because these reductions did not differ between or within the study groups, use of medication does not seem to be a plausible explanation of the findings; although, during the study, the subjects may have used other health enhancing activities that may have influenced the outcome measures.

CONCLUSION

The results of the present study support the efficacy of prescribing various resistance-training programs with Thera-Band elastic bands to patients with OA of the knee as a method to enhance their functional ability and to reduce their knee joint pain.

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