Concentric Versus Combined Concentric-Eccentric Isokinetic Training: Effects on Functional Capacity and Symptoms in Patients With Osteoarthrosis of the Knee

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ABSTRACT Gür H, Çakfın N, Akova B, Okay E, Küçükoğlu S. Concentric versus combined concentric-eccentric isokinetic training: effects on functional capacity and symptoms in patients with osteoarthrosis of the knee. Arch Phys Med Rehabil 2002;83:308-16.

Objective: To compare the effects of concentric and coupled concentric-eccentric isokinetic resistance training on functional capacity and symptoms of patients with osteoarthrosis (OA) of both knees.

Design: Repeated measures.

Setting: A university exercise physiology laboratory.

Participants: Twenty-three volunteers, ages 41 to 75 years. Patients were randomly assigned to 3 groups: concentric (CON, n = 9), concentric-eccentric (CON-ECC, n = 8), and nontreatment (NONTX, n = 6).

Interventions: The CON group performed 12 concentric contractions of each knee extensor and flexor muscles; the CON-ECC group performed 6 concentric and 6 eccentric contractions of each knee muscle group by using a spectrum of angular velocities ranging from 30°/s to 180°/s with 30°/s intervals, for both sides, 3 days a week for 8 weeks.

Main Outcome Measures: Functional capacity (rising from a chair, walking, stair climbing and descending) and pain during rest and activities, peak torque, and cross-sectional area (CSA) of knee muscle groups of subjects were tested before and after training.

Results: Both training groups showed marked decreases ($P < .001$) in pain scores and increases ($P < .001$) in functional capacity together with increases ($P < .05$–.01) in peak torque and CSA of knee muscles. However, the NONTX group did not display these marked changes after the 8-week period. The results also indicated that concentric-eccentric training has a greater influence on functional capacity, especially stair climbing and descending, than that of concentric training when compared with NONTX group; however, the improvements in pain measurements were better in the CON group compared with the CON-ECC group after the training.

Conclusions: The results suggest that with the isokinetic resistance training used in this study, it is possible to improve functional capacity and decrease pain in patients with OA of the knee. The results also showed that extensive training involving a high number of repetitions and eccentric contractions was safe, effective, and well tolerated for the patients with knee OA.

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

OSTEOARTHROSIS (OA) is a slowly evolving articular disease, which appears to originate in the cartilage and affects the underlying bone and soft tissues. The condition occurs late in life, principally affecting large weight-bearing joints such as the knee and the hand.[1] The major symptoms and findings of OA are pain and physical disability.[2] Several studies[3-5] have shown that patients with knee OA have weakness of lower-extremity muscles, particularly the quadriceps muscle, and the degree of quadriceps muscle weakness has been associated both with the degree of pain in the knee and the amount of physical disability. Because it has been reported that pain and disability improve in patients with knee OA after resistance training,[6-9] therapeutic exercise programs as a treatment for knee OA are frequently used in clinics. However, it is not yet known which type of exercise is most beneficial for patients with knee OA.

In daily activities, such as ascending and descending stairs or standing up from or sitting down into a chair, the knee muscles contract concentrically or eccentrically to control the movement of the limb and/or to prevent joint overloading. Although concentric and eccentric contractions are frequently used in daily activities, muscle strength, pain, and disability were investigated in patients with knee OA merely for isometric, isokinetic concentric, and isotonic resistance exercise in previous studies.[4,6,7,9] In addition, it has been suggested that resistance training performed by using eccentric muscle contractions may be more effective than training performed by using concentric or isometric muscle contractions in increasing muscle strength in healthy individuals.[10-12] The greater effectiveness of eccentric or coupled concentric-eccentric training has been attributed to greater changes in neural activation[13] and to greater muscle hypertrophy[14-17] compared with concentric training in healthy individuals.

According to previous findings, we hypothesized that a group of patients with knee OA receiving concentric-eccentric training would produce clinically meaningful improvements in function, particularly stair climbing and descending, and muscle cross-sectional area (CSA) compared with a group of patients receiving only concentric training. Therefore, we proposed to determine the effects of concentric versus combined concentric-eccentric isokinetic training on functional capacity, symptoms, muscle strength, and CSA in patients with bilateral knee OA.

METHODS

Patients

Volunteers were qualified, and 23 patients with bilateral complaints of knee OA, who had grade 2 or 3 OA, as judged

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by criteria of Kellgren and Lawrence,[18] based on weight-bearing radiographs, were admitted in this study. All volunteers went through a medical examination (cardiovascular, respiratory) before the study, and those who did not have any health problems that might pose a risk during the maximal test and training were included in the study. The patients had not undergone any orthopedic procedures that would affect their leg muscle performance. The patients were informed about testing procedures, possible risk, and discomfort that might ensue, and gave their written informed consent to participate. In addition, the investigation was in accordance with the Helsinki Declaration of 1975, as revised in 1983.[19] When the subjects were interviewed about their occupational and leisure-time physical activities, none of them had regularly engaged in leisure-time physical activity such as walking, running, swimming, or other exercise in the last 10 years. All subjects were employed in an office or were retired, spending most of the day sitting. The activity level for all subjects remained relatively constant during the experimental period. The patients were randomly assigned to 3 groups: concentric (CON, n = 9), concentric-eccentric (CON-ECC, n = 8), and nontreatment (NONTX, n = 6).

Functional Capacity Measurements

Patients used a 10-point numeric rating scale (NRS; 0 = minimal functional capacity, 10 = maximal functional capacity) to give a subjective score for rising from a chair, standing, walking, and stair climbing and descending. In addition, functional capacities were measured by a 15-m walk, rising from a chair, and stair climbing and descending tests under standardized conditions.

Walking test. The patients were asked to walk as fast as possible along a level, unobstructed corridor on the command "go." The patients stood before the starting line. A hand-held stopwatch was started as the subjects passed a predetermined start mark and stopped as they passed a second mark 15m from the start mark.

Rising from a chair test. The patients were asked to rise from a chair 10 times as fast as possible without arm support. While patients stood by the chair, the stopwatch was started with the command "go" and stopped when the patients reached the starting position for the 10th time. The patients were informed that they must sit down on the chair with bottom contact and stand up until their knees were fully extended.

Stair climbing test. The patients stood at the bottom of ordinary straight stairs, consisting of 12 steps (17cm high, 23cm wide), and were asked to ascend the stairs as fast as possible on the command "go" without arm support. The stopwatch was started on the command "go" and stopped when patients placed their second foot on the top step (12th) of the stairs.

Descending stair test. The patients stood at the top of the stairs as described previously. When instructed to descend the stairs without arm support, the stopwatch was started on the command "go" and stopped when patients placed their second foot on the floor at the bottom of the stairs.

Two trials with a 5-minute rest interval were performed for all functional tests, and the best one was accepted as a result. A 15-minutes rest period was allowed between each test. The details of the tests' procedures were explained to the patients, and they were allowed to perform a few trials without maximal efforts before the tests for familiarization. To see reproducibility of the tests, 10 patients, who were selected randomly, repeated all functional tests 3 to 4 days after the first tests. The reliability coefficients (r) for repeated measures of the functional tests were excellent and varied from .97 to .99 ($P < .001$).

Knee Pain

Pain was subjectively evaluated by using a 10-point NRS (0 = no pain, 10 = unbearable pain), which assessed the severity of pain in general, at night, after inactivity, sitting, rising from a chair, standing, walking, and stair climbing.[3] Patients were also asked to rate the pain perceived in their knee during the functional capacity tests on a 10-point scale (0 = no pain, 10 = unbearable pain).

Isokinetic Tests

All tests were completed on the Cybex 6000 computer-controlled isokinetic dynamometer,[a] which was calibrated before every test session. Subjects were positioned sitting with the backrest at a 90° angle and were instructed to grip the sides of the seat during the testing. The thigh, pelvis, and trunk were stabilized with straps. An adjustable lever arm was attached to the leg by a padded cuff just proximal to the lateral malleolus. The axis of rotation of the dynamometer arm was positioned just lateral to the lateral femoral epicondyle. Gravity corrections to torque at 45° (0° = straight leg) were calculated by the computer software.

Conventional concentric and eccentric continuous (reciprocal) isokinetic tests were used. During concentric and eccentric tests, the subjects performed 4 maximal reciprocal flexion-extension repetitions for each angular velocity of 60°/s, 120°/s, and 180°/s in both legs. Eccentric tests were performed after concentric tests. A 20-minute rest was allowed between the concentric and eccentric tests and between each leg.

The order of speed was from slower to faster as suggested by Wilhite et al.[20] A 20-second rest was allowed between each contraction speed. The knee moved through the whole range of motion between 10° and 80° (0° = straight leg) during the concentric and eccentric tests. During the tests, the subjects were verbally encouraged to produce maximal efforts by the same individual who administered the tests. The subjects did not have prior experience with the isokinetic dynamometer and were familiarized with testing procedures performing 3 consecutive submaximal warm-up trials for each muscle group and speed, one of which was a maximal contraction as recommended by Snow and Blacklin.[21] After a 20-second rest period, concentric and eccentric peak torque of knee extensor and flexor muscle groups were measured by maximal voluntary contractions (MVCs).

Determination of Muscle CSA

The patients underwent computed tomography[b] for the determination the CSA of the knee flexors (hamstring) and extensors (quadriceps) of both leg. The patients were scanned in supine position in which the leg was elevated to remove compression on the muscle. The same position was adopted by all subjects, and the measurements were repeated to minimize possible postural differences. Axial sections of the midthigh were taken of each patient for both legs at the level of 20cm from medial femoral condyle. Slice thickness was 2mm, and scanning time was 6 seconds. The outline of the knee extensors and flexors were traced visually by using electronic calipers, and the CSA of the encircled area was measured by the scanner's own computer. Specific Houndsfield unit (H) ranges were used to analyze lean tissue (0–200H) and fat tissue (−60 to −100H) areas inside the extensor and flexor muscles. The computed tomography scans were evaluated 3 times, and mean values were recorded as the result. The coefficient of variation between 2 consecutive measurements of CSA was 1.3%. The area was measured in cm^2.

Isokinetic Training

In isokinetic training, the CON group performed 12 concentric extension, concentric flexion movements; the CON-ECC group performed 6 concentric extension, eccentric extension movements, then 6 concentric flexion, eccentric flexion movements by using a spectrum of angular velocities ranging from 30°/s to 180°/s at 30°/s-intervals (ie, 30°, 60°, 90°, 120°, 150°, 180°) bilaterally 3 days a week for 8 weeks. In the CON group, conventional continuous mode was used, and the patients trained reciprocally for the knee extensors and flexors. In the CON-ECC group, concentric-eccentric mode was used, and the instructions given were "Push as hard and as fast as possible against the lever arm (concentric contraction) and at the end of extension; continue to push against the lever arm as it returns to the start position (eccentric contraction)" for knee extensors and vice versa for knee flexors. A 2-minute rest was given between knee extensors and flexors in the CON-ECC group and a 5-minute rest between the legs in both training groups.

The complete set of measurements was performed before and after the training under standardized conditions. The patients in the NONTX group maintained their normal physical activities and received no training but were tested twice throughout the 8-week experimental period. Patients were encouraged by the investigators to produce maximal effort during the training and tests. During the training period, none of the patients had clinical joint effusion, determined by palpation of a bulge sign, and none of the patients took any medication during the experimental period of 8 weeks.

Statistics

Selected physical characteristics of the patients were compared by 1-way analysis of variance (ANOVA). ANOVA was also used to test the differences in baseline values between the groups. The individual differences (% changes) between pre- and posttraining for the variables were calculated by the formula $\Delta S = Post - Pre/Pre \times 100$, and then the differences (% changes) were compared between the groups by ANOVA. Data gathered pre- and posttraining were evaluated by paired t test. To estimate whether changes in the parameters were clinically meaningful, the standardized response means (mean changes/standard deviation [SD]) were measured to calculate effect size: an effect size of .01 to .19 is considered very small; 0.2 to .49, small; 0.5 to .79, moderate; and greater than 0.8, large. The Scheffé test was used for post hoc analysis. To determine reproducibility for the functional tests, intraclass correlations type (1,1) were calculated.[22] The significant level was set at P less than .05. Total scores presented in tables are defined as the sum of the data of each individual.

RESULTS

Patients

The selected characteristics and grade of OA in the patients were not significantly different between the groups (table 1). There were also no statistically significant differences in the tested variables between the groups for baseline values by ANOVA. None of the subjects in the training groups complained of a need to stop training during 8 weeks of training, and they completed the whole training schedule.

Table 1: Selected Physical Characteristics of the 3 Test Groups

	ECC-CON (n = 8)	CON (n = 9)	NONTX (n = 6)
Age (y)	55 ± 12	56 ± 12	57 ± 9
Height (cm)	159 ± 11	156 ± 11	157 ± 7
Body weight (kg)	79.9 ± 5.5	78.2 ± 10.0	79.5 ± 11.8
OA on x-ray*			
Right knee	2.4 ± 1.0	2.3 ± 1.0	2.3 ± 1.0
Left knee	2.5 ± 1.0	2.4 ± 0.4	2.6 ± 1.0

NOTE. No significant differences between groups by ANOVA. Values presented as mean ± SD.
* Rated on the Kellgren scale.

Functional Capacity

The subjective ratings for daily functions were significantly ($P < .05$–.001) improved in the CON-ECC and CON groups by training (table 2). In both of the training groups, the changes (ΔS, %) in the rating as a result of training were significantly ($P < .05$–.01) different compared with the NONTX group after 8 weeks (table 2). The changes, however, were not significantly different between the CON and CON-ECC groups after the training. Except for rising from a chair, the improvements (%) in functional measurements as a result of training were better in the CON-ECC group than in the CON group. The most marked changes were observed in stair climbing and descending, particularly in the CON-ECC group. The effect sizes indicate that both training types resulted in large and meaningful changes in daily functions (fig 1A). Moreover, the level of the effect size was greater in the CON-ECC group compared with the CON group for all variables except rising from a chair. However, the effect size for total score of the subjective ratings of daily functions was large and similar between both groups, with the values of 2.3 and 2.2 (fig 2).

The functional capacities of the 15-m walk, rising from a chair, and stair climbing and descending also improved significantly ($P < .01$–.001) with the training (table 3). The changes (ΔS, %) in functional capacity as a result of training were significantly ($P < .05$–.01) different in the CON-ECC and CON groups compared with the NONTX group after 8 weeks, except for the 15-m walk in both training groups and descending stairs in the CON group. The most marked percentage of change was observed in the CON-ECC group for descending stairs. The effect size was moderate to large (.62–1.02) in the CON-ECC group and small to large (.43–.86) in the CON group (fig 1B). For total score of the functional tests, the effect size was greater in the CON-ECC group compared with the CON group, with the value of 1.00 and .88, respectively (fig 2).

Pain

Subjective ratings of pain for the selected daily life activities decreased ($P < .01$–.001) after 8 weeks of training in both the CON-ECC and CON groups but not in the NONTX group (table 4). The changes (ΔS, %) in pain scores were significantly ($P < .05$–.001) different in the training groups compared with the NONTX group. However, the change in total score was not significantly greater in the CON group than in the CON-ECC group, with the mean values of 69% ± 12% versus 53% ± 18%, respectively (table 4). The pain during the functional tests was also decreased ($P < .01$–.001, table 5) in both training groups, but the effect of training mode on scores was not as clear as observed in the daily activities. The effect size was large and meaningful for both of the training groups, but the level of size was remarkably greater in the CON group compared with the CON-ECC group for all parameters of daily functions (fig 1C). For pain during the functional tests, the effect sizes were also large and clinically meaningful in both

Table 2: Results of Subjective Ratings of the Functional Capacity (10-point NRS scale) at Baseline and After 8 Weeks and the Differences (ΔS, % Change) in the 3 Groups

	CON-ECC (n = 8)		CON (n = 9)		NONTX (n = 6)	
	BL	8W	BL	8W	BL	8W
Rising from a chair	6.3 ± 1.0	7.8 ± 0.7*	6.3 ± 1.0	8.2 ± 0.8†	6.0 ± 0.6	6.3 ± 0.8
% change		23 ± 10§		31 ± 8¶		6 ± 9
Standing	6.9 ± 2.0	8.6 ± 1.1*	7.1 ± 0.9	8.7 ± 0.9*	7.3 ± 0.5	7.2 ± 0.4
% change		33 ± 23‖		23 ± 11§		−2 ± 5
Walking	6.6 ± 1.3	8.4 ± 0.9‡	7.1 ± 1.2	8.7 ± 1.0‡	7.7 ± 0.5	7.5 ± 1.0
% change		29 ± 16‖		23 ± 10§		−2 ± 10
Stair climbing	5.0 ± 1.4	7.8 ± 1.1*	6.1 ± 1.5	8.4 ± 1.0*	6.7 ± 1.0	6.5 ± 1.4
% change		55 ± 41‖		43 ± 27§		−3 ± 10
Descending stair	5.1 ± 1.8	7.1 ± 1.4‡	6.3 ± 1.3	8.2 ± 1.3*	6.2 ± 1.3	6.5 ± 1.4
% change		49 ± 37‖		32 ± 13§		−7 ± 13
Total score	29.9 ± 6.1	39.5 ± 3.8*	33.0 ± 5.3	42.2 ± 4.6*	33.8 ± 3.4	33.3 ± 4.8
% change		35 ± 22‖		29 ± 10‖		−2 ± 5

NOTE. Values are mean ± SD.
Abbreviations: BL, baseline; 8W, 8 weeks.
* $P < .05$ between BL and 8W by paired *t* test.
† $P < .01$ between BL and 8W by paired *t* test.
‡ $P < .001$ between BL and 8W by paired *t* test.
§ $P < .05$ compared with the NONTX group by ANOVA.
‖ $P < .01$ compared with the NONTX group by ANOVA.
¶ $P < .001$ compared with the NONTX group by ANOVA.

training groups (fig 1D). The effect sizes for total score of pain during daily functions and during the functional tests were greater in the CON group compared with the CON-ECC group (fig 2).

Cross-Sectional Area

The CSA of the quadriceps increased ($P < .01$) in both training groups, but there were no significant differences among the groups for the changes (table 6). The CSA of the hamstring also increased significantly ($P < .05$–.001, table 6) with training, but the percentage of change was not significantly different between the groups. The effect size of training was small for the hamstring and very small for the quadriceps (fig 2).

Muscle Strength

Because similar changes as a result of isokinetic training were observed in both knees of the patients after 8 weeks, the data gathered on the patients' dominant side were presented in this study. The gains in peak torques after training were highly dependent on the muscle action used for training and testing. The improvements in concentric peak torque of quadriceps muscle by training were significant ($P < .05$–.01) in just the CON group at 120°/s and 180°/s of angular velocities, and the changes (ΔS, %) in the CON group were greater ($P < .05$) than the other groups (fig 3). In contrast to concentric peak torque, the improvements in eccentric peak torque of quadriceps were significant ($P < .05$) in just the CON-ECC group at all angular velocities (fig 3). In addition, eccentric peak torque of quadriceps muscle was significantly ($P < .05$) improved in the CON group only at 120°/s (fig 3).

For the hamstring, significant ($P < .05$–.01) improvements in concentric peak torque were observed for both training groups at all angular velocities, but it was most striking for the CON group at 180°/s (fig 4). For eccentric peak torque of the hamstring, although the significant ($P < .05$) improvements

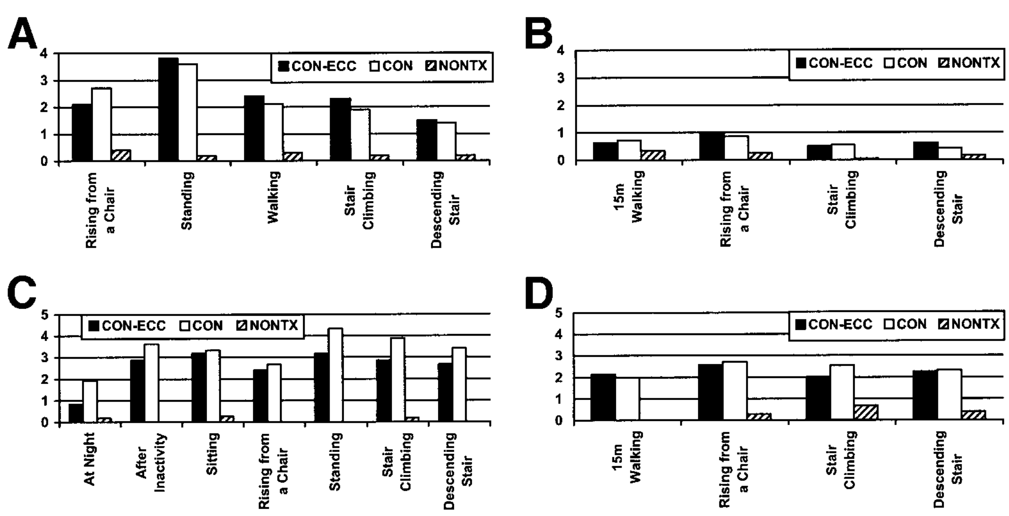

Fig 1. The effect size in CON-ECC, CON, and NONTX groups for (A) subjective rating of daily functions, (B) functional tests, (C) pain during daily functions, and (D) pain during functional tests.

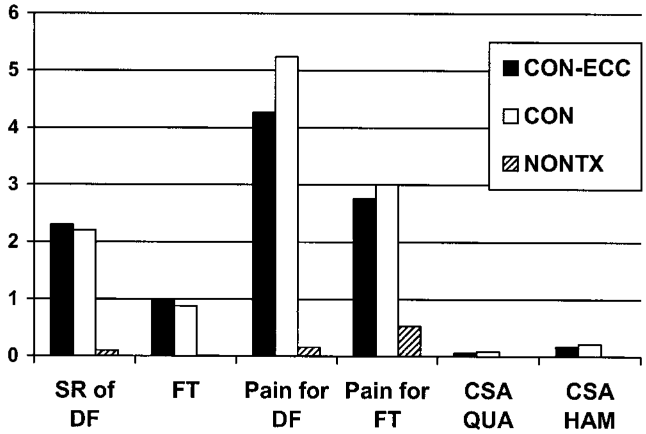

Fig 2. The effect size in CON-ECC, CON, and NONTX groups for total scores of subjective rating (SR) of daily functions (DF), functional tests (FT), pain during daily functions, pain during functional tests, and CSA of quadriceps (QUA) and hamstring (HAM).

were observed in both training groups at 60°/s and 120°/s, the change was significant only for CON-ECC group at 180°/s (fig 4).

DISCUSSION

In summary, both training groups showed marked decreases in pain scores and increases in functional capacity, as well as a significant increase in peak torque and CSA of knee muscles. Because NONTX group patients were tested twice during the 8-week period and did not display these marked changes, it is difficult to attribute the improvements in training groups to the learning curve for the tests' procedures. The improvements in functional measurements were better in the CON-ECC group, particularly for stair climbing and descending, than that of the CON group when compared with the NONTX group; however, the improvements in pain measurements were better in the CON group compared with the CON-ECC group after training. There was no such difference in muscle CSA resulting from training type. Moreover, improvement in muscle strength was related to the contraction type of the training because concentric strength improved significantly in the CON group, whereas eccentric strength improved significantly in the CON-ECC group.

In the patients with severe OA, a strenuous strength exercise program including eccentric contractions has not been attempted before, presuming that they might be harmful to the knee. Another concern might be that pain could limit the outcome of such programs or increase the pain. Although we used 72 maximal trails in a wide spectrum of angular velocity from slow to fast, no patients withdrew because of adverse effects or complaints either for the CON group or the CON-ECC group. The subjective ratings of pain scores significantly improved for daily activities in both groups, however, more successful pain reduction was observed in the CON group.

The subjective ratings of the functional capacity (table 2) show that both training groups improved functional capacity, but it was more remarkable in the CON-ECC group. As expected, concentric-eccentric training was more effective on the capacity of stair climbing and descending compared with concentric training. Because it was reported that descending and ascending stairs performances are the most impaired function of OA patients compared with healthy subjects,[23] the results of our study seem to be important. Fisher et al[6] used isometric plus isotonic training programs lasting 16 weeks in a similar group of patients with knee OA. They found that improvements in walk time and functional capacity were approximately 9% after 8 weeks and approximately 14% and 18%, respectively, after 16 weeks.[6] In the our study, after 8 weeks of training, the improvement in walk time was similar to Fisher's[6] results, but the functional capacity in our study improved more than twice that of Fisher's results. Moreover, the improvements in the functional capacity observed in our study were approximately 2 times better than the improvement seen after 16 weeks in Fisher's[6] study. Fisher[6] observed the most important improvements in pain during walking, standing, rising from a chair, and climbing stairs, with a value of 30% for 16 weeks of training and 10% for 8 weeks of training. These parameters improved 53% and 69% in the CON-ECC and CON groups, respectively, for 8 weeks of training in our study.

In another study, Fisher et al[7] investigated the effects of a rehabilitation program, which included stretching and resistance exercise 3 days a week for 3 months, on the functional performance and pain in subjects with knee OA. Although the test parameters in our study differed from theirs, the improvements in function and pain observed in our study are greater

Table 3: Results of Functional Tests at Baseline and After 8 Weeks and the Differences (ΔS, % Change) in 3 Groups

	CON-ECC (n = 8)		CON (n = 9)		NONTX (n = 6)	
	BL	8W	BL	8W	BL	8W
15-m walk	9.85 ± 1.16	8.94 ± 0.81*	10.21 ± 1.68	9.17 ± 1.65*	10.04 ± 1.37	10.56 ± 1.48
% change		−9 ± 6		−10 ± 6		5.0 ± 3.3
Rising from chair	25.67 ± 7.31	19.52 ± 3.95†	24.82 ± 2.66	19.66 ± 3.12*	25.41 ± 6.73	23.93 ± 5.37
% change		−22 ± 8§		−20 ± 12§		−4 ± 9
Stair climbing	6.38 ± 1.73	4.88 ± 0.74*	6.62 ± 1.56	4.95 ± 1.03*	7.24 ± 3.09	7.08 ± 2.57
% change		−21 ± 11‡		−23 ± 15‡		−0.2 ± 6
Stair descending	6.75 ± 2.22	4.58 ± 0.74†	6.95 ± 2.42	5.44 ± 2.42*	7.55 ± 2.37	8.50 ± 4.63
% change		−29 ± 12‡		−23 ± 13		9 ± 29
Total score	48.60 ± 12.10	37.92 ± 5.94†	48.64 ± 4.88	39.22 ± 6.19*	50.18 ± 9.25	50.07 ± 12.10
% change		−21 ± 8§		−19 ± 9§		−0.3 ± 8

NOTE. Values are mean ± SD. in seconds.
* $P < .01$ between BL and 8W by paired *t* test.
† $P < .001$ between BL and 8W by paired *t* test.
‡ $P < .05$ compared with the NONTX group by ANOVA.
§ $P < .01$ compared with the NONTX group by ANOVA.

Table 4: Results of Pain (10-point NRS scale) at Baseline and After 8 Weeks and the Differences (ΔS, % Change) in 3 Groups

	CON-ECC (n = 8)		CON (n = 9)		NONTX (n = 6)	
	BL	8W	BL	8W	BL	8W
At night	3.8 ± 2.1	1.5 ± 0.8*	4.4 ± 1.7	1.4 ± 1.3†	3.2 ± 1.5	3.5 ± 1.6
% change		−52 ± 24‡		−72 ± 21‡		17 ± 53
After inactivity	5.3 ± 1.3	3.0 ± 1.8†	4.1 ± 0.9	1.2 ± 1.1†	3.8 ± 0.8	3.8 ± 0.8
% change		−47 ± 28§		−72 ± 25‖		0 ± 0
Sitting	3.5 ± 1.5	1.1 ± 1.0†	3.4 ± 1.3	0.9 ± 0.9†	2.5 ± 1.0	2.7 ± 0.5
% change		−72 ± 25§		−77 ± 26§		8 ± 39
Rising from a chair	5.4 ± 1.2	2.5 ± 1.1†	5.2 ± 1.5	2.0 ± 0.9†	4.7 ± 1.2	4.7 ± 1.2
% change		−57 ± 15‖		−61 ± 18‖		−2 ± 5
Standing	3.5 ± 1.6	1.6 ± 1.5†	4.0 ± 1.0	1.4 ± 1.1†	4.0 ± 0.6	4.0 ± 0.6
% change		−61 ± 33§		−66 ± 28§		0 ± 13
Stair climbing	6.5 ± 0.9	3.5 ± 1.6†	5.8 ± 1.4	1.7 ± 0.9†	4.8 ± 1.3	5.0 ± 0.8
% change		−46 ± 22‡		−68 ± 19‖		5 ± 25
Descending stair	6.6 ± 1.1	3.4 ± 1.5†	5.8 ± 1.4	1.7 ± 1.0†	5.0 ± 1.5	5.0 ± 0.9
% change		−48 ± 23‡		−66 ± 15§		2 ± 15
Total score	35.8 ± 6.1	16.6 ± 7.3†	33.9 ± 7.7	10.3 ± 4.5†	27.3 ± 3.8	28.0 ± 5.2
% change		−53 ± 18§		−69 ± 12§		3 ± 16

NOTE. Values are mean ± SD.
* $P < .01$ between BL and 8W by paired *t* test.
† $P < .001$ between BL and 8W by paired *t* test.
‡ $P < .05$ compared with the NONTX group by ANOVA.
§ $P < .01$ compared with the NONTX group by ANOVA.
‖ $P < .001$ compared with the NONTX group by ANOVA.

even though they[7] used a longer exercise session (1h) and duration (3mo) compared with our study. When we compared the results of our study with several studies, which used traditional and aerobic exercises for OA,[24-26] the functions and symptoms of the patients in these studies did not improve after the training as well as they improved in our study.

Maurer et al[27] recently conducted an isokinetic concentric exercise study in the elderly with knee OA. The subjects in their study underwent strength training of knee extensors unilaterally with an isokinetic dynamometer 3 times a week for 8 weeks. During the exercise, they used a total of 27 concentric contractions at the angular velocities of 90°/s, 120°/s, and 150°/s. When we calculated the improvements in pain and function in Maurer's study[27] based on mean values, they ranged from 8% to 36% for pain and from 5% to 45% for function. In the our study, for the CON group who used the same contraction type of training, the variables of pain and function improved in ranges from 61% to 77% and from 10% to 43%, respectively. When the results of both studies are compared, in general, it is clear that pain was reduced after training more than twice as much in our study, even in the CON-ECC group, which used eccentric contractions (range, 46%–78%). However, training volume was bigger in the our study with additional speed (30°/s, 180°/s) and contractions compared with Maurer's study.[27] Another difference between these studies is in exercised muscle and limbs (quadriceps vs quadriceps-hamstring, unilateral vs bilateral training) used. These differences between the studies might be the reason for the observed differences in training effects. Moreover, bilateral training involving both knee muscles of the quadriceps and hamstring may be preferable to improve overall function and pain in the patients. In the light of these findings, we conclude that the particular mode of isokinetic therapy used in our study may get better results in function, particularly specific daily

Table 5: Results of Pain During Functional Tests (10-point NRS scale) at Baseline and After 8 Weeks and the Differences (ΔS, % Change) in the 3 Groups

	CON-ECC (n = 8)		CON (n = 9)		NONTX (n = 6)	
	BL	8W	BL	8W	BL	8W
15-m walk	3.9 ± 1.2	1.0 ± 1.1*	3.7 ± 1.1	1.0 ± 1.1*	3.5 ± 1.2	3.5 ± 1.5
% change		−78 ± 21‡		−70 ± 37‡		−1 ± 14
Rising from a chair	5.4 ± 1.8	1.8 ± 1.8*	4.6 ± 1.2	0.8 ± 1.0*	3.8 ± 1.3	4.2 ± 1.5
% change		−71 ± 28†		−66 ± 48†		13 ± 31
Stair climbing	4.6 ± 1.4	1.5 ± 1.7*	4.7 ± 1.1	0.9 ± 0.9*	3.7 ± 1.5	4.7 ± 1.5
% change		−70 ± 36†		−69 ± 45†		10 ± 23
Descending stair	5.3 ± 0.9	1.8 ± 1.8*	4.6 ± 1.1	1.0 ± 1.2*	4.7 ± 1.9	5.3 ± 1.2
% change		−68 ± 33†		−66 ± 41†		2 ± 27
Total score	19.1 ± 3.7	6.0 ± 6.0*	17.4 ± 3.8	3.1 ± 3.3*	15.5 ± 5.0	18.0 ± 4.5
% change		−72 ± 28‡		−71 ± 41‡		6 ± 17

NOTE. Values are mean ± SD in seconds.
* $P < .001$ between BL and 8W paired *t* test.
† $P < .05$ compared with the NONTX group by ANOVA.
‡ $P < .01$ compared with the NONTX group by ANOVA.

Table 6: Results of CSA of Dominant Leg at Baseline and After 8 Weeks and the Differences (ΔS, % Change) in the 3 Groups

	CON-ECC (n = 8)		CON (n = 9)		NONTX (n = 6)	
	BL	8W	BL	8W	BL	8W
Quadriceps	47.8 ± 8.0	49.5 ± 9.4†	46.1 ± 10.1	47.1 ± 9.9†	46.3 ± 12.2	46.2 ± 11.9
% change		3.2 ± 3.7		3.0 ± 2.2		0.0 ± 1.4
Hamstring	25.5 ± 6.4	26.9 ± 7.5*	23.5 ± 7.7	25.3 ± 8.1‡	23.7 ± 8.7	23.8 ± 7.8
% change		5.3 ± 5.5		8.1 ± 7.9		2.4 ± 5.0

NOTE. Values are mean ± SD in cm^2. No significant differences among the groups by ANOVA.
* $P < .05$ between BL and 8W by paired *t* test.
† $P < .01$ between BL and 8W by paired *t* test.
‡ $P < .001$ between BL and 8W by paired *t* test.

activities like stair climbing and descending, and pain in older people with knee OA.

The findings of this study showed that the gains in isokinetic strength after concentric- and concentric-eccentric–coupled isokinetic training is dependent on the muscle action used for training and testing. Concentric-eccentric–coupled training is more effective than concentric training for development of eccentric isokinetic strength, and concentric training is more effective than concentric-eccentric training for development of concentric isokinetic strength. A test mode specificity in the adaptation of strength training was previously reported by several investigators.[17,28] Hurley and Newham[4] used a rehabilitation program including 4 sets of 6 isometric MVCs, 4 sets of 6 isokinetic MVCs at 60°/s, and 4 sets of 6 isokinetic MVCs at 120°/s in the patients with unilateral osteoarthritic knee. They measured peak forces at 0°/s, 30°/s, 60°/s, 90°/s, 120°/s, and 180°/s. When we calculated improvements in percentage based on the figure in their study,[4] quadriceps strength of the diseased leg increased significantly from approximately 40% to 70% at all angular velocities, except 180°/s after the rehabilitation program. Improvements in strength in their study[4] were greater than the improvements found in our study. The patients in our study, however, had more severe disease scoring than the patients in their study and our patients had bilateral OA whereas the Hurley and Newham[4] patients had unilateral OA. Because they did not objectively assess the effects of the program on the functional capacity and pain of the patients, we cannot compare our results with their results to determine how the improvements in muscle strength influence the function and pain.

Rogind et al[8] also investigated physical function and pain in patients with severe knee OA. They used a rehabilitation program including general fitness, balance, coordination, stretching, and lower extremity muscle strength exercises twice in a week for 3 months. After their program, peak torques of extensor and flexor muscles of the knee at 30°/s improved 20% and 40%, respectively, together with the improvement in pain at night and rest and weight bearing. However, the selected functional tests such as walking speed, stair climbing, and rising from a chair were not changed in their study. Although Rogind[8] used a different training program than we did, the functional test results in our patients improved remarkably together with muscle strength.

In Maurer et al's study,[27] the improvements in isokinetic concentric extension torque based on mean values were 20% and 16% at 90°/s and 120°/s of angular velocities, respectively. In our study, isokinetic extension peak torques were 10%, 21%, and 30% at the angular velocities of 60°/s, 120°/s, and 180°/s, respectively, in the CON group. However, in the CON group, our patients performed exercise at 30°/s, 60°/s, and 180°/s of angular velocities in addition to 90°/s, 120°/s, and 150°/s, which were used in Maurer's study[27] with 3 more contractions for each speed of contraction. In addition, we found concentric peak torque of the hamstring to be improved more than the peak torque of quadriceps in both training groups. Because it was reported that hamstrings play an important role in the stability of the knee, these findings may be valuable for the patients' function and symptoms. It is well known that, with aging primarily, a decline in rapid power production is observed. Therefore, a great improvement of peak torques ob-

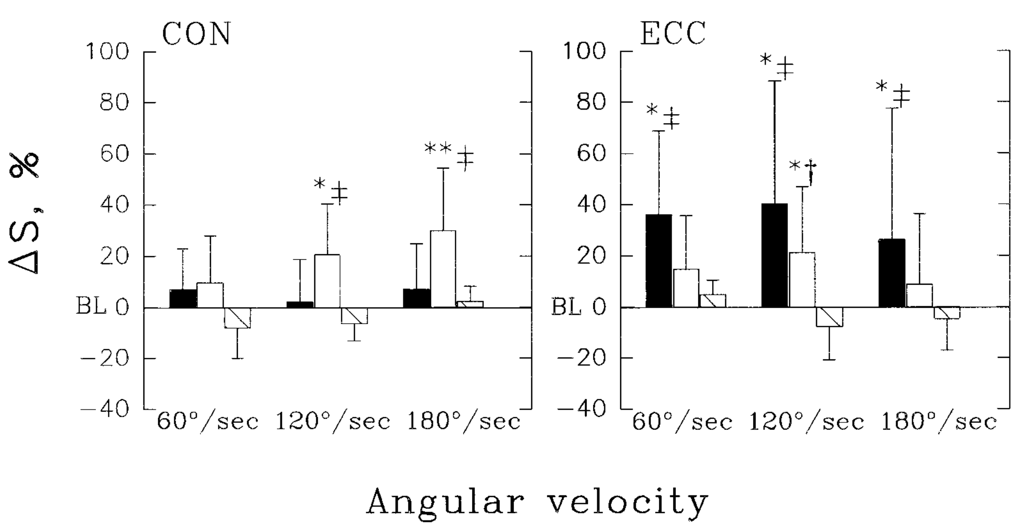

Fig 3. The changes (ΔS, %) in concentric and eccentric peak torque of dominant knee quadriceps after 8 weeks in the CON-ECC group (shaded bar), CON group (open bar), and NONTX group (dashed bar). *$P < .05$, **$P < .01$ compared with baseline by paired test. †$P < .05$ compared with NONTX group by ANOVA. ‡$P < .05$ compared with other groups by ANOVA.

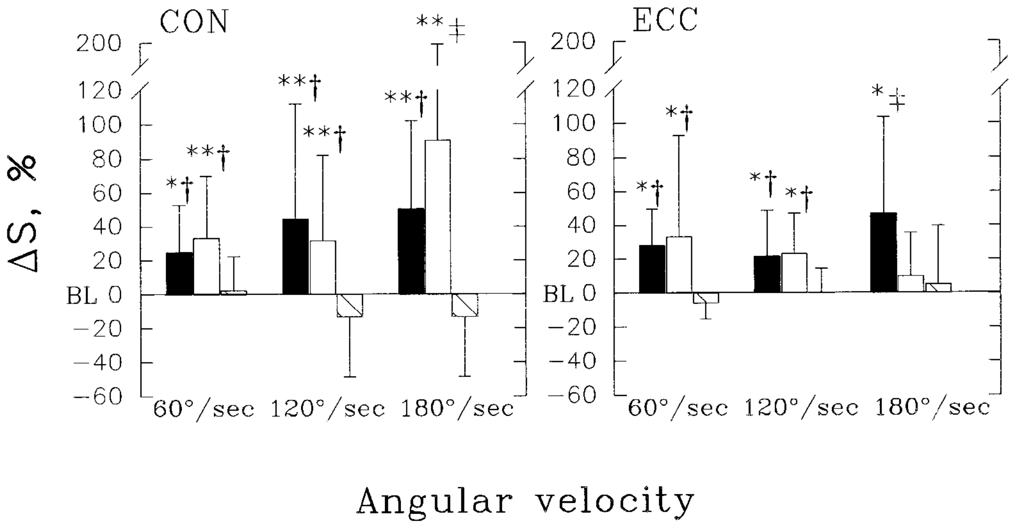

Fig 4. The changes (ΔS, %) in concentric and eccentric peak torque of dominant knee hamstring after 8 weeks in the CON-ECC group (shaded bar), CON group (open bar), and NONTX group (dashed bar). *$P < .05$, **$P < .01$ compared with baseline by paired test. †$P < .05$ compared with NONTX group by ANOVA. ‡$P < .05$ compared with other groups by ANOVA.

served in the fast test speed in isokinetic measurements may also be another advantage of the exercise program we used for the elderly with knee OA.

Increases in strength after the training are caused by muscular or neural adaptations. In trained quadriceps and hamstrings, concentric and eccentric strengths increased more than the change in their CSA. Therefore, the increment in muscle strength should be explained partly by the increment in muscle CSA in our study. Because neural activation was not measured in our study, there is no chance to discuss the effects of the training on neural mechanisms. Further studies are needed to investigate neural adaptations or activation in agonist (synergistic) and antagonist muscles resulting from isokinetic concentric and eccentric training in the patients with knee OA.

Based on previous studies, we hypothesized that concentric-eccentric training would cause greater muscle hypertrophy than concentric training. Our findings do not support this hypothesis. However, the subjects in the previous studies based on our hypothesis were healthy and young. To find similar muscular hypertrophy in the CON training group compared with the CON-ECC training group indicates that an eccentric phase of contraction is not necessary for muscular hypertrophy in the group of the patients involved in our study.

CONCLUSION

Our results showed that with the training programs used in this study, it is possible to improve functional capacity and to decrease pain in the patients with knee OA 2 to 3 times better than those reported in the similar studies. However, the small number of subjects involved in the groups of our study limits the authors in making a generalization. The results indicated that concentric-eccentric–coupled isokinetic training has a slightly better influence on the functional capacity of the patients, especially stair climbing and descending, compared with concentric isokinetic training. The results also showed that extensive training involving a high number of repetitions and eccentric contractions is safe, effective, and well tolerated for the patients with knee OA. A training regimen involving quadriceps and hamstring muscles in both knees with bilateral knee OA may be more optimal to improve overall function and symptoms in patients. Because concentric and eccentric muscle actions are used consecutively in most daily activities, training for older patients with knee OA should involve both types of actions.

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