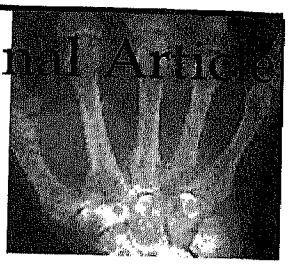
Original Article



Effects of a Cross-Training Exercise Program in Persons with Osteoarthritis of the Knee
A Randomized Controlled Trial

Lucie Péloquin, Gina Bravo, Pierre Gauthier, Guy Lacombe, Jean-Sébastien Billiard

This study was designed to evaluate, by means of a randomized controlled trial, the effects of a physical activity program incorporating aerobic, strength, and stretching exercises in individuals with osteoarthritis of the knee. We randomly assigned 137 volunteers ages ≥50 to an experimental group or a control group. The experimental group participated in three 1-hour sessions of supervised exercises per week over a 3-month period. The control participants were instructed to continue their usual daily activities, and they attended 1-hour education sessions twice a month. The effectiveness of the program was evaluated using repeated measurements of parameters related to self-reported health status, physical capacity, and joint tenderness.

After 3 months, significantly greater improvements were observed in the experimental group than the control group in terms of: arthritis pain ($p = 0.02$), ability to walk and bend ($p = 0.03$), aerobic capacity ($p < 0.0001$), hamstring and low back flexibility ($p = 0.003$), quadriceps and hamstring strength ($p < 0.01$), and the perception of changes relating to osteoarthritis of the knee and general condition ($p < 0.0001$). However, no significant differences were observed between the groups in isokinetic strength of the quadriceps (all p's > 0.05), joint tenderness ($p = 0.18$), and health perception ($p = 0.7$). The overall results suggest that this program is effective for older persons with osteoarthritis of the knee and that it could contribute to maintaining their independence and improving their quality of life. **(J Clin Rheumatol 1999;5:126–136)**

Key words: Osteoarthritis of the knee, Physical training, Older

Osteoarthritis is the most common rheumatic disease (1), affecting nearly 3 million Canadians (2) and approximately 16 million Americans (3). The joints most frequently affected are the small joints in the hand and, second, the knee (4). Among older people, this chronic disease of the musculoskeletal system is one of the most frequent causes of loss of independence (5).

In 1994, Ettinger and Afable (6) proposed a model to explain the process by which osteoarthritis of the knee may lead to physical disability. According to this model, pain in the knee(s) limits the use of the lower extremities, which adversely affects the 3 main components of physical capacity, that is, aerobic capacity, muscle strength, and flexibility. In this regard, previous studies have shown a much larger decrease in aerobic capacity, muscle strength, and flexibility in individuals with osteoarthritis of the knee compared with age- and sex-matched apparently healthy individuals (7–10). Finally, the model postulates that reduced physical capacity has a substantial impact on the ability to perform daily life activities such as going up and down stairs, getting up from a chair, standing, and walking.

Over the last few years, therapeutic exercise has received in-

Institut universitaire de gériatrie de Sherbrooke (LP, GB, PG, GL), Faculté de médecine, Université de Sherbrooke (GB, GL), Faculté d'education physique et sportive, Université de Sherbrooke (PG), Québec, Canada; Hôpital de St-Étienne (J-SB), St-Étienne, France.

Address correspondence to: Lucie Péloquin, PhD, Centre de recherche, Institut universitaire de gériatrie de Sherbrooke, 1036, Belvédère sud, Sherbrooke (Québec), Canada J1H 4C4. Fax: (819) 829-7141.

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creasing attention as a safe, beneficial treatment for osteoarthritis of the knee (11). According to Ettinger and Afable's model (6) and the opinion of some experts in the field (12–14), the objectives of therapeutic exercise for persons with osteoarthritis should be the following: to increase aerobic capacity; to maintain or restore range of movement and flexibility; and to increase muscle strength and endurance. Consequently, the program that would be most beneficial to these people should include aerobic, strength, and stretching exercises (12).

Numerous studies have investigated the effects of different types of exercise programs in individuals with osteoarthritis of the knee (15–31). These programs were composed almost exclusively of aerobic, resistance, or flexibility exercises, with some containing a mixture of 2 types of exercises. Recently, the efficacy of aerobic and resistance training was compared in a well designed large scale trial lasting 18 months (32). However, no studies have yet evaluated the efficacy of a systematic program containing aerobic, strength, and flexibility exercises. Therefore, the main objective of the present study was to evaluate, by means of a randomized controlled trial, the effects of a supervised physical activity program incorporating these 3 types of exercises on several aspects of the health of individuals with osteoarthritis of the knee.

METHODS

Participants

All participants were volunteers from the Sherbrooke (Quebec, Canada) metropolitan area who responded to various advertising media. All volunteers were examined by the research team physician using a standardized procedure. In addition, recent (<12 months) or new x-rays of the participants' knees were evaluated by a radiologist before enrollment in the study to determine the severity of the disease. The first step in selecting the volunteers involved verifying the following criteria by telephone: a) age ≥50, b) no contraindication to participating in a supervised exercise program, (c) not expecting to be absent from the city for more than 2 weeks; d) having an independent, non-institutional lifestyle, e) not having intra-articular steroid or viscoelastic device injections within the 2 months preceding the intervention period, and f) a stable regimen for using analgesics or nonsteroidal anti-inflammatory drugs for at least 2 weeks before the beginning of the intervention. In the second step, the participants who met these criteria were examined by the physician to verify that they presented the following criteria: g) a diagnosis of minimal to moderate idiopathic osteoarthritis of one or both knee joints (33), h) <15° of fixed-flexion deformity, i) <10° of *genu varum or genu valgum*, and (j) no joint blocking. In the third step, the radiologist verified the severity of the disease from the x-rays. Only those participants who had a grade 1, 2 or 3, as judged by the Kellgren and Lawrence criteria (34), were included.

Over a 6-month period, nearly 400 persons contacted the recruitment coordinator. Of these, 267 met the criteria that could be documented by telephone and 250 agreed to be examined by the physician. A total of 152 met all eligibility criteria. Of this total, 15 refused to participate for various reasons. Therefore, 137 attended the initial evaluation and agreed to participate in the study by signing a consent form. Before the beginning of the study, the research protocol was approved by the Ethics Committee of the Youville Hospital.

Design

This was an experimental study using the pretest, post-test design with a control group. Prepared from random number tables, randomization was blocked and stratified by age, sex, and the severity of the disease.

Outcome Measurements

The following variables were measured before and after the intervention. All the measurements were taken under the same conditions (i.e., order of administration of the tests, time of day) by the same evaluators. Each evaluator was assigned to specific tests and had received prior training. Evaluators were blinded to the assigned group. The evaluation of each participant lasted approximately 2 hr.

Health Status

The Arthritis Impact Measurement Scales 2 (AIMS2) was used for measuring the physical, social, and psychological health status of the participants (35). The AIMS2 is a 78-item self-administered questionnaire. In the present study, only the first 57 items were used to measure participant outcome. The 57 items fall into 12 subscales which assess various aspects of health status. Each scale contains 4 or 5 items. The scores for each of the subscales vary from 0 to 10, where 0 represents good and 10 poor health status. The AIMS2 has been validated with patients with numerous rheumatic diseases, including osteoarthritis. The internal consistency coefficients of these 12 subscales vary from 0.74 to 0.96 and their test-retest reliability from 0.78 to 0.94 (35). Validity analyses in osteoarthritic individuals have shown that patient designation of an area as a problem or as a priority for improvement was significantly associated with a poorer AIMS2 score in that area (35).

Self-Rated Health

Self-rated health was measured with a question used in numerous health surveys, including Canadian health promotion surveys and national U.S. surveys

(36). It asks the patient to rate his or her health on a scale going from excellent (1 point) to poor (5 points) compared with people of the same age. The validity of this scale is based on a strong correlation between self-rated health and the presence of specific health problems (37).

Physical Capacity

Aerobic capacity. The participants' aerobic capacity was evaluated with the "5-minute walking field test" developed specifically for participants with arthritis (38). Before testing, the participant was instructed to walk at as brisk a pace as possible, but one he or she could maintain for 5 min. The observer verbally encouraged each participant to walk as fast as possible throughout the test. Each participant was evaluated individually. The distance walked was recorded in meters. Test-retest reliability is 0.92 ($p = 0.0001$) and the distance walked in 5 min correlates significantly ($r = 0.80$, $p = 0.0001$) with the VO_2 max value measured by a maximal treadmill test (39).

Quadriceps and hamstring strength. Isometric and isokinetic strength were measured using a Cybex II dynamometer (Cybex Division of Lumex, Inc., Ronkonkoma, NY). After a warm-up period of 4 full contractions (2 extension/flexion cycles) at a 30° angle, the participant executed 4 isometric full contractions (2 extension/flexion cycles without any pause between) at a 30° then a 60° angle. The score recorded was the better of the 2 torques generated by each muscle group at each angle. Isokinetic strength was evaluated next. The participant first executed 4 sub-maximal contractions (2 extension/flexion cycles) and 2 full contractions (1 extension/flexion cycle) at a set rate of 30°/s to become familiarized with the test. Next, the participant executed 4 full isokinetic contractions (2 extension/flexion cycles with a 20-s pause between) at a rate of 30°/s, then 90°/s. The score recorded was the better of the 2 torques generated by each muscle group at each rate. Finally, the same procedure was repeated to evaluate the quadriceps and hamstring strength of the other leg. During the test, the evaluator verbally encouraged the participant to produce his or her maximum effort. To keep strength measurements valid, they were corrected for the effect of gravity. Test-retest reliability and concomitant validity coefficients for torque measurements using this apparatus are very high, 0.995 and 0.999 respectively (40).

Hamstring and low back flexibility. Hamstring and low back flexibility were measured using the "sit-and-reach test" (41). The participant was asked to sit on the floor with the legs extended on either side of a graduated ruler fixed to the floor. The participant then placed his or her hands one on top of the other at the beginning of the ruler and slid them forward as far as possible along the ruler to achieve maximum trunk flexion; he or she had to maintain this position for 2 s. The participant had to repeat this movement 4 times. The flexibility score recorded (in inches) was the better of the final 2 tests. The test-retest reliability of this measurement is 0.94 (42).

Joint Tenderness

Joint tenderness was measured using Doyle's (43) joint index, which was specifically designed for patients with osteoarthritis. The evaluation consists of exercising firm pressure on the joint margin or making a passive movement with the joint being measured. Tenderness is quantified on a 4-point scale based on 4 precise criteria. The test-retest coefficient of variation of this index is approximately 0.8% (43).

At the end of the intervention, all participants were asked to answer a questionnaire to determine whether they had observed any change in their osteoarthritis or general condition since the beginning of the study. If they answered yes, they had to specify these changes.

Confounding Variables

To verify the study's internal validity, 3 variables that could affect the efficacy of the exercise program were measured before and after the intervention period. These variables were: 1) physical exercise habits, measured with the 7-day recall (44), 2) weight, and 3) frequency of use of medications for osteoarthritis during the month preceding the evaluation, measured with a questionnaire.

Interventions

The experimental volunteers participated in three 1-hr sessions of supervised exercises per week over a 3-month period. Each exercise session was divided into 3 parts. The session began with a 5-min warm-up period comprising alternating exercises designed to warm up the muscles and joints and moderately activate the cardiorespiratory system. The second part of the session, lasting approximately 50 min, consisted of systematically executing the 3 types of exercises chosen for this study. The first activity was a brisk walk designed to improve aerobic capacity. Second, the participants did a series of exercises specifically designed to develop the muscle strength of the quadriceps, hamstrings, abductors, gastrocnemii, abdominals, pectorals, deltoids, trapezoids, biceps, and triceps. The strength exercises were done using a progressive resistance system

. . .three 1-hr sessions of supervised exercises per week over a 3-month period.

called "Thera-Band" (Hygenic Corporation, Akron, OH). Third was the resistance program, which started with quadriceps and hamstring isometric contractions at 3 different angles to build strength. After 2 weeks, isotonic contractions of the quadriceps and hamstrings were introduced. Other muscle groups were gradually added as the exercise program progressed. The intensity of isotonic contractions was controlled through the maximum number of repetitions (MR) that could be done for each exercise. Elastic bands of various tension were provided to attain the expected MR for each exercise. The stretching regimens were then used to adequately stretch the exercised muscles. Depending on the muscle group selected, the participant moved the corresponding joint through its full range of motion and held this position for 15 s. The exercise was repeated twice with a rest of similar duration between the exercises. For the first 2 weeks, only sub-maximal range of motion was allowed to prepare the articulation for maximal stretch. Approximately 17 min were allocated to each of the 3 types of exercise. The session ended with a 5-min cool-down period during which the participants were asked to relax. The detailed progression followed for each type of exercise is described in Table 1.

The control participants continued their usual daily activities and, to minimize attention bias, they attended 1-hour education/information sessions twice a month. The sessions covered various aspects related to their osteoarthritic condition. It was not feasible for the experimental group to attend the information sessions. To ensure that participation in the exercise program was the only difference between the 2 groups, a summary of the information sessions was given to the experimental participants a few days after. Also, to avoid any contamination, the exercise and information sessions took place at different times. Finally, the participants in both groups were asked to inform the research coordinator if they had received any intra-articular corticosteroid or viscoelastic product injection in the knee(s) during the same period. If so, these participants had to be excluded from the study.

Sample Size

The health status variable was chosen to estimate the number of participants in the study. In previous studies evaluating the effects of an exercise program on the variable of interest in this population, the reported standard deviation varied between 0.68 and 3.0 units, for a total score varying between 0 and 10 for each subscale (24). To avoid underestimating the variation, the maximum value, 3.0, was used. The clinically important difference to detect was set at 1.5, which corresponds to an average standardized effect (45). Setting alpha (unilateral) at 5% and beta at 20%, 50 participants per group were sufficient to satisfy the preceding restrictions. This number was increased to 59 per group to take into account a drop-out rate of 15% during the study.

Statistical Analyses

Statistical analyses of the data were performed with SAS software (SAS Institute Inc., Cary, NC). The first step in the analysis consisted of describing the participants' characteristics. *T* tests for independent samples were then applied to the dependent and confounding variables which were continuous and normally distributed to evaluate the equivalence of the 2 groups at baseline. For the variables for which the normality was not satisfactory, Mann-Whitney's non-parametric test was applied, and for the categorical variables, the chi-square or Fisher's exact test was used. The second step consisted of studying the impact of the program on the dependent variables. The continuous, normally distributed variables were analyzed using an analysis of variance for repeated measurements. The degree of significance of the Group X Time interaction was used to judge the positive effect of the program. The variables for which the normality was not satisfactory or which were categorical variables were analyzed using non-parametric tests (Mann-Whitney, chi-square or Fisher's exact test) comparing the 2 groups with regard to the changes that occurred over time. Finally, the confounding variables were analyzed using parametric or non-parametric tests depending on the type of variable to verify the distribution of the variables between the 2 groups before and after the intervention period. The significance level was set at 0.05. All reported p values are for 2-tailed tests.

RESULTS

Group Comparisons at Baseline

During the intervention period, 13 participants (9.5%) dropped out of the study, 10 from the experimental group, and 3 from the control group. The most frequently cited reasons for dropping out were the occurrence of a medical problem unrelated to the interventions and a lack of time. However, one participant was forced to quit after knee inflammation because of the exercises performed. The 13 who dropped out were compared with the 124 participants who participated to the end of the study. The participants who dropped out had the following characteristics: a lower education level, more difficulty performing their household tasks, fewer social activities, and more joint pain. Finally, a larger percentage of those who dropped out were separated or divorced.

Of the 124 participants who were remeasured at the end of the study, 59 were from the experi-

TABLE 1. Progression followed for each type of exercise[a]

WEEK(S)	AEROBIC EXERCISES	MUSCLE-STRENGTHENING EXERCISES	STRETCHING EXERCISES
1–2	3 × 4 min rest: 1 min 40%–50% HRR	Isometric (Q + H) 1 × 3 rep (3 angles) 6 s cont/6 s rest (4 ex)	3 × 15 s/ex[b] (2–5 ex)
3	2 × 8 min rest: 2 min 40%–50% HRR	Isotonic (4–6 ex) 1 × 15 MR	2 × 15 s/ex (4–7 ex)
4	12 + 6 min rest: 2 min 50%–60% HRR	Isotonic (6–8 ex) 1 × 15 MR	2 × 15 s/ex[c] (7–8 ex)
5–7	1 × 15 min 50%–60% HRR	Isotonic (7–10 ex) weeks 5–6: 1 × 15 MR week 7: 1 × 12 MR	2 × 15 s/ex (8–11 ex)
8–9	1 × 16 min Work toward 60% HRR	Isotonic (8–11 ex) 1 × 12 MR	2 × 15 s/ex (8–11 ex)
10–12	1 × 17 min Work toward 60% HRR	Isotonic (9–11 ex) 1 × 10 MR	2 × 15 s/ex (9–12 ex)

HRR, heart rate reserve; Q, quadriceps; H, hamstring; rep, repetitions; s, seconds; cont, contraction; ex, exercises; MR, maximum repetitions.

[a]Average intensity achieved during walking periods varied between 47 and 56% of HRR.

[b]Sub-maximal range of motion.

[c]Full range of motion.

mental group and 65 from the control group. The statistical analyses comparing the 2 groups at baseline revealed no significant difference between the groups with the exception of the "household tasks" subscale ($p = 0.01$); here the control group participants needed slightly more help to do the tasks. With regard to the confounding variables, no significant difference was observed between the 2 groups between the beginning and end of the study. The characteristics of the experimental and control participants at baseline are shown in Table 2.

Compliance

Compliance was measured by noting the attendance of each participant in the exercise or information sessions. During the intervention period, a total of 36 exercise sessions were held. The average compliance of the experimental participants was 86% (range = 39%–100%). For the control group participants, who were asked to attend a total of 6 information sessions, the compliance rate was 82% (range = 33%–100%).

Outcomes

Significant differences between the experimental and control groups were observed for only 2 of the 12 health aspects assessed by the AIMS2. Participants in the experimental group showed greater improvements than the control group in the "walking and bending" and "arthritis pain" subscales. The participants in both groups had significantly less difficulty performing the activities measured by the "walking and bending" subscale after the intervention period. Although a significant improvement was observed for both groups, the improvement observed in the experimental participants was significantly greater than that observed in the controls ($p = 0.03$). The intensity and frequency of arthritic pain also diminished significantly in both groups, but once again, the reduction was significantly greater in the experimental group than the control group ($p = 0.02$). Pre- and post-test AIMS2 results are shown in Table 3.

Table 4 reports the results of the tests measuring the participants' physical capacity. A significant difference was observed between the experimental group and the control group in regard to aerobic capacity. The significant interaction effect ($p = 0.0001$) demonstrates the positive effect of the program on aerobic capacity despite a slight increase observed in the control participants. The same was true for the performance of the experimental participants on the flexibility test, which, once again, the interaction effect was significant ($p = 0.003$). The results obtained for quadriceps and hamstring isometric and isokinetic strength are reported for the muscles surrounding the most affected knee radiologically and for the muscles surrounding the less affected or unaffected knee. With the

TABLE 2. Descriptive characteristics of experimental and control participants at baseline

VARIABLES	EXPERIMENTAL GROUP n = 59	CONTROL GROUP n = 65	p VALUE
Age (yr)	65.64 ± 7.41[a]	66.43 ± 8.29	0.58
Sex			
Female	42 (71.19%)[b]	45 (69.23%)	
Male	17 (28.81%)	20 (30.77%)	0.81
Severity of the disease Grade			
1	14 (23.73%)	16 (24.62%)	
2	24 (40.68%)	28 (43.08%)	
3	21 (35.59%)	21 (32.31%)	0.93
OA duration (yr)	7.92 ± 7.90	6.38 ± 6.05	0.55
Unilateral	19 (32.20%)	19 (29.23%)	
Bilateral	40 (67.80%)	46 (70.77%)	0.72
Other affected joint(s)			
Yes	54 (91.53%)	53 (81.54%)	
No	5 (8.47%)	12 (18.46%)	0.11
BMI (kg/m²)	29.79 ± 4.51	29.77 ± 4.83	0.98
Marital status			
Married	36 (61.02%)	36 (55.38%)	
Separated	3 (5.08%)	4 (6.16%)	
Widowed	11 (18.64%)	16 (24.62%)	
Never married	9 (15.25%)	9 (13.85%)	0.40

OA, osteoarthritis; BMI, body mass index.
[a] = mean ± SD.
[b] = N (%).

exception of hamstring isometric strength of the most affected knee measured at a 30° angle, significant differences between the 2 groups were observed for all the results obtained on the quadriceps and hamstring isometric strength test at the 2 angles evaluated. With regard to the quadriceps isokinetic strength test, no significant difference was observed between the groups at either rate of movement. However, for hamstring isokinetic strength, significant differences were observed between the 2 groups at both rates of movement.

Finally, no significant differences between the experimental and control groups were observed in joint tenderness ($p = 0.18$) and self-rated health ($p = 0.70$). Results concerning these outcomes are summarized in Table 5.

In the questionnaire distributed to the participants at post-test asking if they had observed any changes in their knee osteoarthritis or general condition since the beginning of the study, significant differences were observed between the 2 groups ($p < 0.0001$). In the experimental group, 91.5% of the participants said they had noticed some positive changes in the knee osteoarthritis compared with only 24.6% of the controls. Similar results were observed with regard to the participants' general condition; 93.2% of the experimental participants reported positive changes compared with only 21.5% of the controls.

DISCUSSION

After 3 months of intervention, significantly greater improvements were observed in the experimental than the control group for the following variables: the "walking and bending" and "arthritic pain" subscales, aerobic capacity, hamstring and low back flexibility, quadriceps isometric strength, hamstring isometric and isokinetic strength, and the perception of a positive change with regard to the knee osteoarthritis and general condition.

The subjective evaluation of the impact of the program using the AIMS2 clearly demonstrates the efficacy of the exercise program on the "walking and bending" and "arthritic pain" subscales. A 23.5% improvement was observed with regard to the intensity and frequency of arthritic pain in the experimental participants. This result is similar to those reported by other studies that evaluated an exercise program of the same duration as that of the present program; significant reductions in pain varying from 15% to 23.5% were observed after programs comprising primarily aerobic or strength exercises (25, 26, 28, 46). In a much longer study, Ettinger et al. (32) found only 12% and 8% improvement in knee pain scores after 18 months of aerobic and resistance training, respectively. As mentioned by the authors, a compliance rate of only 50% at 18 months could explain the smaller effects they observed compared with previous studies.

TABLE 3. Impact of the program on each subscale of the AIMS2

VARIABLES	EXPERIMENTAL GROUP		CONTROL GROUP		
HEALTH STATUS (0–10)	PRETEST	POST-TEST	PRETEST	POST-TEST	p VALUE[a]
Mobility level	1.30 ± 1.33[b]	1.08 ± 1.11	1.57 ± 1.45	1.58 ± 1.33	0.24
Walking and bending	3.14 ± 2.43	1.64 ± 1.89[c]	3.43 ± 2.61	2.89 ± 2.78[d]	0.03
Hand and finger function	0.87 ± 1.53	0.52 ± 1.08	0.61 ± 1.23	0.62 ± 1.29	0.47
Arm function	0.37 ± 0.73	0.26 ± 0.61	0.43 ± 0.77	0.39 ± 1.10	0.67
Self-care tasks	0.04 ± 0.20	0.05 ± 0.33	0.19 ± 0.54	0.06 ± 0.39	0.08
Household tasks	0.12 ± 0.49	0.11 ± 0.45	0.82 ± 1.99	0.35 ± 1.23[c]	0.06
Social activity	5.42 ± 1.60	5.34 ± 1.65	5.45 ± 1.54	5.42 ± 1.48	0.99
Support from family and friends	2.36 ± 2.38	1.85 ± 2.26[d]	2.47 ± 2.25	1.93 ± 1.88	0.91
Arthritis pain	4.53 ± 2.02	3.09 ± 1.54[c]	4.53 ± 2.20	3.94 ± 2.22[c]	0.02
Work	1.80 ± 2.08	0.89 ± 1.13[d]	1.39 ± 1.49	1.28 ± 1.64	0.12
Level of tension	3.64 ± 1.88	3.03 ± 1.95[c]	3.74 ± 1.81	3.45 ± 2.02	0.11
Mood	1.72 ± 1.36	1.54 ± 1.46	1.77 ± 1.40	1.70 ± 1.57	0.74

[a]Significance test comparing experimental group and control group on changes that occurred over time.
[b]Mean ± SD.
[c]Indicates a significant change over the 3-month period at the 0.01 level.
[d]Indicates a significant change over the 3-month period at the 0.05 level.

The present program also significantly improved one or more aspects measured by the "walking and bending" subscale of the AIMS2. This improvement was about 39.4%, which corresponds to a reduction of 1.5 ± 2.03 units. Two other studies used this AIMS subscale to measure the impact of a predominantly aerobic program on the ability of their osteoarthritic participants to do these activities. These studies reported significant reductions of 0.89 ± 1.9 units (46) and an improvement of 39% (24), respectively.

With regard to the other 10 health aspects measured by the AIMS2, no significant differences were observed between the 2 groups. The absence of change on these 10 aspects could imply that, taken overall, the program had only a minimal impact on health status. However, an analysis of the factors that may have limited the improvement observed on these aspects provides some indication that the reported health status improvement was substantial. In fact, the little effect observed on the following health aspects: mobility level, hand and finger function, arm function, self-care tasks, and household tasks, could be related to the low scores obtained (i.e., low disability) by the participants at pretest. These low scores reveal a ceiling effect that makes potential improvement difficult. A recent study reported that certain AIMS subscales, particularly those measuring social and psychological aspects, were not very sensitive to change (47). This weak sensitivity could account for the lack of effect observed in this study on the "social activity" and "support from family and friends" aspects, and on "level of tension" and "mood". A more responsive disability questionnaire, such as that used in the Fitness Arthritis and Senior Trial study (32), should be used in future studies of the effects of exercise in patients with osteoarthritis. Ettinger et al. (32) reported a 10% improvement in self-rated physical disability after an 18-month aerobic exercise program and a 8% improvement in the participants who performed resistance exercises.

The exercise program did not reduce joint tenderness significantly more in the experimental than in the control participants. This stability could be attributable to the almost complete absence of inflammation in the participants' joints. According to Doyle et al. (43), joint tenderness is a reflection of inflammation in osteoarthritis. The scores obtained on this variable at pretest suggest that the participants' joints at baseline were not very inflamed, thus leaving little room for improvement.

The experimental participants significantly improved their walking distance by 12.8% after the exercise program. This improvement is lower than that observed in the study by Kovar et al. (24), in which the distance walked in 6 min increased from 381 to 451 meters, that is, an 18% change, after an exercise program for persons with osteoarthritis of the knee. The main component of their program, which lasted only 8 weeks, was a 30-min walk. The greater improvement observed in the latter study with a shorter exercise period could have resulted from a much lower initial aerobic capacity level in these participants compared with the experimental participants in the present study. To date, only one study has used the 5-min

TABLE 4. Impact of the program on physical capacity

VARIABLES	EXPERIMENTAL GROUP PRETEST	EXPERIMENTAL GROUP POST-TEST	CONTROL GROUP PRETEST	CONTROL GROUP POST-TEST	*p* VALUE[d]
Aerobic capacity (meters)	419.19 ± 75.18[a]	467.77 ± 74.27[c]	406.93 ± 84.95	425.58 ± 84.79[c]	0.0001
Hamstring and low back flexibility (inches)	19.19 ± 4.71	22.08 ± 4.48[c]	17.59 ± 4.76	19.17 ± 4.52[c]	0.003
Quad isometric strength (Nm)					
Angle 30°					
Most affected knee	63.68 ± 27.36	69.73 ± 28.31[b]	62.77 ± 26.44	60.63 ± 25.38	0.008
Less (or un)affected knee	66.83 ± 28.21	71.42 ± 29.93[b]	66.14 ± 26.67	63.23 ± 27.77	0.005
Angle 60°					
Most affected knee	95.53 ± 44.37	104.88 ± 47.04[c]	88.89 ± 39.31	85.08 ± 37.34	0.007
Less (or un)affected knee	102.44 ± 46.47	108.76 ± 47.31[c]	92.17 ± 38.22	91.73 ± 42.87	0.027
Hams isometric strength (Nm)					
Angle 30°					
Most affected knee	39.27 ± 22.68	45.80 ± 21.19[c]	33.08 ± 18.95	36.95 ± 17.88[c]	0.149
Less (or un)affected knee	39.71 ± 21.96	46.22 ± 22.14[c]	33.69 ± 20.13	35.71 ± 18.84	0.006
Angle 60°					
Most affected knee	41.27 ± 21.33	45.29 ± 22.53[c]	36.29 ± 18.05	37.27 ± 17.44	0.013
Less (or un)affected knee	42.75 ± 24.11	48.02 ± 22.81[c]	37.37 ± 19.93	37.03 ± 18.17	0.0001
Quad isokinetic strength (Nm)					
Angular velocity 30°/s					
Most affected knee	105.10 ± 46.58	110.17 ± 49.55	104.57 ± 44.29	98.31 ± 40.81	0.065
Less (or un)affected knee	115.95 ± 49.48	118.80 ± 51.15	109.57 ± 41.80	107.56 ± 44.76	0.282
Angular velocity 90°/s					
Most affected knee	80.61 ± 36.19	85.08 ± 37.36	82.05 ± 37.46	82.15 ± 33.64	0.398
Less (or un)affected knee	88.53 ± 38.30	89.88 ± 38.16	82.03 ± 31.61	83.37 ± 34.67	0.726
Hams isokinetic strength (Nm)					
Angular velocity 30°/s					
Most affected knee	55.64 ± 33.82	64.88 ± 32.42[c]	50.65 ± 26.48	53.90 ± 27.24	0.017
Less (or un)affected knee	58.29 ± 32.77	64.85 ± 33.07[c]	54.83 ± 28.41	55.71 ± 30.58	0.013
Angular velocity 90°/s					
Most affected knee	48.08 ± 28.44	66.02 ± 34.32[c]	44.47 ± 28.25	56.29 ± 28.28[c]	0.048
Less (or un)affected knee	51.27 ± 30.87	67.75 ± 34.23[c]	49.83 ± 26.49	56.77 ± 31.04[c]	0.002

Quad, quadriceps; Nm, newton-meters; Hams, hamstring; s, seconds.
[a]Mean ± SD.
[b]Indicates a significant change over the 3-month period at the 0.05 level.
[c]Indicates a significant change over the 3-month period at the 0.01 level.
[d]Significance test comparing experimental group and control group on changes that occurred over time.

walking test to assess the effects of an exercise program on the aerobic capacity of participants with arthritis (38). After a predominantly aerobic 3-month exercise period, the authors found that the distance increased by about 8%, which is slightly lower than the 12.8% result obtained in the present study. This 4.8% difference could also be related to a difference in the initial aerobic capacity of the participants. Therefore, the improvements obtained in the present study are comparable to previously reported results of programs comprising primarily aerobic exercises.

A significant improvement of 2.89 ± 2.74 inches was observed in hamstring and low back flexibility in the experimental participants in the present study. This improvement is higher than those reported by Minor et al. (46) after a 12-week exercise period for participants with osteoarthritis of the weight-bearing joints who participated in a predominantly aerobic (0.85 inch) or flexibility (1.9 inches) exercise program.

The percentage improvements observed for quadriceps isometric strength of the experimental participants varied between 8.4% and 17.1% and those for hamstring isometric strength between 15.3% and 35.9%. These results are comparable to or slightly lower than those reported by studies that evaluated the efficacy of programs that involved individuals with osteoarthritis of the knee doing isometric exercises during each exercise session (21, 25, 26, 28, 29). However, the number of exercises that produced the improvement in the strength of these muscle groups

TABLE 5. Impact of the program on joint tenderness and self-rated health

VARIABLES	EXPERIMENTAL GROUP PRETEST	EXPERIMENTAL GROUP POST-TEST	CONTROL GROUP PRETEST	CONTROL GROUP POST-TEST	p VALUE[d]
Joint tenderness					
Knee score (0–6)	0.81 ± 1.12[a]	0.66 ± 1.09	0.66 ± 1.14	0.62 ± 1.13	0.88
Total score (0–144)	7.88 ± 8.99	5.34 ± 7.07[c]	6.26 ± 6.90	4.57 ± 5.23[c]	0.18
Self-rated health					
Excellent	8 (13.56%)[b]	9 (15.25%)	7 (10.77%)	13 (20.00%)	
Very good	21 (35.59%)	29 (49.15%)	22 (33.85%)	20 (30.77%)	
Good	21 (35.59%)	14 (23.73%)	16 (24.62%)	28 (43.08%)	
Fair	9 (15.25%)	7 (11.86%)	18 (27.69%)	4 (6.15%)	
Poor	0 (0.00%)	0 (0.00%)	2 (3.08%)	0 (0.00%)[c]	0.70

[a]Mean ± SD.
[b]= N(%).
[c]Indicates a significant change over the 3-month period at the 0.01 level.
[d]Significance test comparing experimental group and control group on changes that occurred over time.

was much larger and these studies did not include a control group in their protocol, which casts some doubt on the true impact of their program on this type of strength.

Concomitant significant increases occurred for hamstring isokinetic strength. The experimental participants in the present study obtained significant improvements varying between 20.6% and 69.4%. These results are similar to those showing the existence of a strong correlation between isometric and hamstring isokinetic strength both in healthy individuals (48, 49) and in persons with osteoarthritis of the knee (50). In this regard, it is difficult to explain the lack of a significant improvement in the quadriceps muscle group of the experimental participants. In osteoarthritic participants comparable to ours, Ettinger et al. (32) also found, in both of their exercise groups, a significant gain in hamstring isokinetic strength with no change in quadriceps isokinetic strength. They did not comment on these results. A tentative explanation is that the quadriceps of ambulatory patients with knee osteoarthritis are frequently called on by dynamic muscle contractions that occur regularly at different speeds and intensities during walking in particular. Hence, their training programs and ours may have failed to provide the proper stimulation needed to provoke a gain in quadriceps isokinetic strength. A possible reason is that the training intensity of this muscle group was too low or inaccessible to these patients, because the development of strength is restricted by a lower knee pain tolerance associated with this exercise.

The physical tests used to measure the participants' performance on the physical capacity components produced an objective picture of the results obtained by the subjective measurements. In view of the improvements observed, however, it is surprising to find that the experimental participants did not view themselves as being in better health than the control participants after the exercise program. Although a valid question was used to measure this variable, the question is probably not formulated in a way that allows persons with a chronic disease to express the concept of change or improvement. Therefore, it is possible that they felt a positive change in their general condition, performed better on the walking tests, and had less pain after the program, without, however, perceiving themselves to be in better health than a person of the same age who does not have a chronic disease or any other health problem.

Possible limitations of the study should be kept in mind when interpreting our results. First, the control group received much less intervention than the exercisers. Hence, it is possible that part of the effects observed in the experimental group is attributable to a Hawthorne effect. A second limitation is the use of the AIMS2 to document the effects of the exercise program on the participants' overall health. As mentioned previously, the absence of change on most subscales of the AIMS2 should not be taken as proof of the uneffectiveness of the intervention, but as an indication of the lack of responsiveness of the scale and of its inability to truly reflect participants' disability at baseline. Third, some improvements were seen in the controls. This suggests that part of the effect noticed in the exercisers is not caused by the intervention to which they were exposed. Three factors may explain the improvements seen in the con-

trol group. First, education has been shown to be effective in reducing pain and disability from osteoarthritis (51–51). Second, the level of attention given to the control participants could have motivated them enough to give a better performance post-test. Improvements could also reflect a learning effect resulting from the short time between pre- and post-test measurements. Physical performance tests are especially prone to that bias (42). However, it must be remembered that even though the control group showed significant improvement on some outcomes, the experimental group improved significantly more than the control group on these outcomes.

CONCLUSION

Despite the limitations cited above, the results of this study strongly suggest that a cross-training program that systematically includes aerobic, resistance, and flexibility exercises is effective in reducing arthritic pain and physical disability. Considering that such a physical training program is a relatively inexpensive nonmedical intervention that is safe and efficient for improving the global health of patients with knee osteoarthritis, we believe it should be included in the treatment plan of these patients.

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