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Open Versus Closed Kinetic Chain Exercises for Patellofemoral Pain

A Prospective, Randomized Study

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ABSTRACT

The goal of this prospective study was to evaluate the efficacy of open versus closed kinetic chain exercises in the nonoperative management of patellofemoral pain. Sixty patients were randomized into a 5-week program that consisted of only closed kinetic chain exercises or only open kinetic chain exercises. Muscle characteristics, subjective symptoms, and functional performance were evaluated in this study at the time of the initial physical examination, at the end of the treatment period, and 3 months later. Both groups experienced a statistically significant decrease in pain and an increase in functional performance. This study shows that both open and closed kinetic chain exercise programs lead to an improved subjective and clinical outcome in patients with anterior knee pain. The few significantly better functional results for some of the tested parameters in the closed kinetic chain group suggest that this type of treatment is a little more effective than the open kinetic chain program in the treatment of these patients.

Patellofemoral pain is the most prevalent disorder involving the knee.[7,8,11,17,31] It is generally agreed that patellofemoral pain should be managed initially by nonoperative rather than by operative means. Nonoperative treatments for patellofemoral pain remain varied and controversial. Today, little consensus exists regarding the most appropriate nonoperative treatment. Open kinetic chain leg extension exercises have been the traditional means of strengthening the quadriceps muscle.[6,20] However, several authors report that these exercises exacerbate symptoms in many patients with patellofemoral pain.[8,22,29]

The clinical use of closed kinetic chain exercises has significantly increased during the past several years. One of the reasons these exercises have received increased attention within the rehabilitation community is that they simulate and replicate many functional movements. Since studies have shown that the major changes as a result of strength training are task-specific,[24,27,28] it may be better to incorporate the rehabilitation into task-related practice. As such, specificity of training becomes a significant factor.[24,28]

In addition, it has been suggested that closed kinetic chain exercises are safer than open kinetic chain exercises because the former place minimal stress on the patellofemoral joint in the functional range of motion.[15,16,24,29,30] Therefore, patients with patellofemoral pain syndrome may tolerate closed kinetic chain exercises better and consequently may exhibit better functional results after such a rehabilitation program.[29] Although these studies have documented the potentially deleterious effects of open kinetic chain exercises in patients with patellofemoral pain, no clinical studies to date have been undertaken to scientifically prove this. Powers[25] recently stated that of utmost importance are clinical trials aimed at determining which treatment procedures are most effective in reducing the symptoms associated with patellofemoral pain. The purpose of this study was to investigate, in a randomized, prospective study, the efficacy of open versus closed kinetic chain exercises. Specifically, we wanted to determine whether closed kinetic chain exercises offer any advantages over conventional open kinetic chain rehabilitation protocols. To our knowledge, this is the first prospective, randomized study in the published

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literature designed to compare the effects of open and closed kinetic chain exercises in patients with patellofemoral pain.

MATERIALS AND METHODS

Subjects

Between November 1995 and May 1997, 60 patients, with an average age of 20.3 years (range, 14 to 33), with patellofemoral pain were randomized, by opening a sealed and numbered envelope, into a 5-week rehabilitation protocol that consisted of only closed kinetic chain exercises (N = 30) or only open kinetic chain exercises (N = 30). Both rehabilitation groups consisted of 10 men and 20 women. The duration of symptoms before the beginning of this study averaged 15.1 months (range, 6 weeks to 28 months). Consistent with the findings in previous studies,[1,29] we observed bilateral patellofemoral pain in about half of the patients (27 of the 60 patients in this study). Fifteen of these patients followed the open kinetic chain exercise program, and 12 followed the closed kinetic chain program ($P = 0.74$). For statistical analysis, only one knee of each of the 27 patients with bilateral pain was evaluated; the most painful knee in each case.

The criteria for inclusion in this study were based on those used by Insall et al.[18] To be eligible for the study, subjects had to have experienced anterior knee pain for more than 6 weeks and had to exhibit two of the following criteria on initial assessment: pain on direct compression of the patella against the femoral condyles with the knee in full extension, tenderness on palpation of the posterior surface of the patella, pain on resisted knee extension, and pain with isometric quadriceps muscle contraction against suprapatellar resistance with the knee in slight flexion. Patients with knee problems other than patellofemoral pain were excluded from the study. Also excluded from this study were patients with a history of a knee operation.

All subjects signed an institutionally approved informed consent statement. All patients received their therapy in the physical therapy department of the Catholic University of Leuven hospital under the direct supervision of a trained physical therapist experienced in knee rehabilitation. The patients were trained for 30 to 45 minutes, three times a week. During the 5-week training program, patients were not allowed to participate in sports. No medication was prescribed as part of their treatment. No brace or tape was used by any patient in this study. Every patient followed the exercise program for the required period of 5 weeks. After the training period, the patients were advised to maintain their muscle strength, but no follow-up of any kind was done between the 5-week evaluation and that at 3 months (the final outcome assessment).

Before the beginning of the open and closed kinetic chain exercise programs, a 10-repetition maximum was determined. On the basis of that information patients were instructed to train at 60% of their maximum. A new 10-repetition maximum was established at the end of a week of training. In both training groups, each exercise was repeated 3 sets of 10 repetitions. The patients rested 1 minute after the conclusion of each set.

In the open kinetic chain exercise protocol, each exercise was held isometrically for a count of 6 seconds with a 3-second rest between repetitions. Each exercise in the closed kinetic chain protocol was performed dynamically with a 3-second rest between repetitions.

The open kinetic chain exercise program consisted of 1) maximal static quadriceps muscle contractions (quadriceps muscle setting) with the knee in full extension, 2) straight-leg raises with the patient supine, 3) short arc movements from 10° of knee flexion to terminal extension, and 4) leg adduction exercises in the lateral decubitus position.

The closed kinetic chain exercise program consisted of 1) seated leg presses, 2) one-third knee bends on one leg and on both legs, 3) stationary bicycling, 4) rowing-machine exercises, 5) step-up and step-down exercises, and 6) progressive jumping exercises.

In both training protocols the patients were instructed to perform the conventional static quadriceps, hamstring, and gastrocnemius muscle stretching exercises after each training session. All subjects were instructed to perform three repetitions of a 30-second static stretch of these muscle groups.

Evaluation

Before the beginning of their rehabilitation program and after 5 weeks of training, all patients were evaluated on several outcome measurements. All patients were reviewed again 3 months after completing their rehabilitation program.

Subjective Outcome Assessment. Pain and discomfort during rest and various activities were recorded on 18 100-mm visual analog scales, where 0 indicated no pain and 100 indicated extremely intense pain.

The combined subjective and functional evaluation of the knee was made with the standardized scoring scale described by Kujala et al.[21] This scale is specifically designed for patients with patellofemoral pain, and is a 0-to-100-point scale (100 = best score) evaluating pain during stair-climbing, squatting, running, jumping, and prolonged sitting with the knees flexed; the presence of a limp, swelling, and subluxation; the amount of quadriceps muscle atrophy and flexion deficiency; and the need for support when walking.

Functional Outcome Assessment. Three functional evaluations were performed in the same order for each patient immediately after instructions were given. In this study, we used a unilateral squat test, a step test, and a triple-jump test. During the unilateral squat test the patients were asked to perform a maximal single knee bend without pain. The maximal flexion angle in the knee was measured according to the guidelines of the American Academy of Orthopaedic Surgeons.[13] A patient who was able to perform a full knee bend without experiencing pain was registered as symptom-free for this test. For the evaluation of the step test, patients were asked to step up and down a 10-cm step. If they did not experience pain, the height of the step was increased by 5 cm until pain occurred. This height was recorded. If the patients were able to step up and down a step of 45 cm without pain, the test ended and the patients were registered as symptom-free for this test. For the triple jump test, the patients were instructed to stand on their injured leg and to jump three times along a straight line. The total distance was measured in centimeters; in addition, the patients were instructed to score their pain and discomfort during this test on a 100-mm visual analog scale.

Muscle-Strength Measurement. To document the possible improvements in quadriceps or hamstring muscle strength due to the rehabilitation protocol, an isokinetic strength measurement was performed on the Cybex 350 dynamometer (Lumex Corp., Ronkonkoma, New York). Concentric knee extensor and flexor peak torque was measured at three speeds: 60, 180, and 300 deg/sec. Each subject was positioned according to the instructions accompanying the instrument.

Muscle-Length Measurement. The tightness of the hamstring, quadriceps femoris, and gastrocnemius muscles was measured goniometrically. Hamstring muscle tightness was tested with the subject supine. The examiner lifted one of the straightened limbs and measured the angle at the hip.[13] To test the quadriceps femoris muscle, the subject was placed in a prone position. The knee was maximally flexed, while the foot of the noninvolved side was placed on the floor with the hip in 90° of flexion. In this position, the angle in the knee was measured.[13] The tightness of the gastrocnemius muscle was obtained by having the patient lean on solid support 0.60 meters (2 feet) away with the tested leg behind the other while keeping the knee of the tested leg extended. The subjects were instructed to maximally flex their tested ankle while keeping their heel to the floor.

Statistical Analyses

A mixed-design repeated-measures analysis of variance was used to compare the baseline results with the 5-week and 3-month assessments across the two treatment groups (mixed-design ANOVA, type general linear model) if the variables were continuous. Changes in the categorical variables across groups and between the different evaluation periods were performed by using Pearson's chi-square test. The observed differences were located by post hoc multiple comparisons for tests of homogeneity. Significance was accepted at the 0.05 level. Using this probability level and a power of 80%, a sample size of 52 (26 patients per group) was necessary.

RESULTS

At initial evaluation (time 0), statistical analyses did not reveal significant differences for any of the evaluated variables between the open and closed kinetic chain groups ($P > 0.05$). No significance difference in the prestudy duration of symptoms was observed ($P = 0.55$) between the two groups.

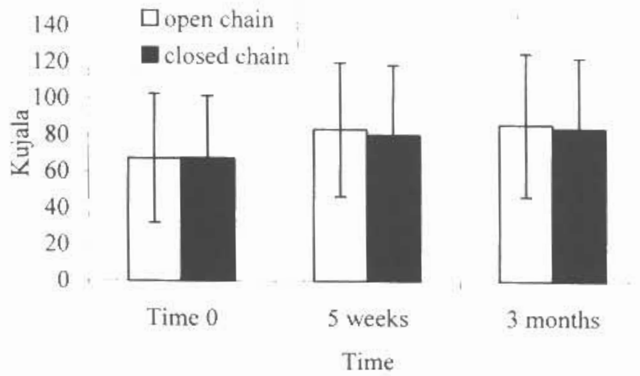

Figure 1. Mean values of both groups on the Kujala scale at the different evaluation periods.

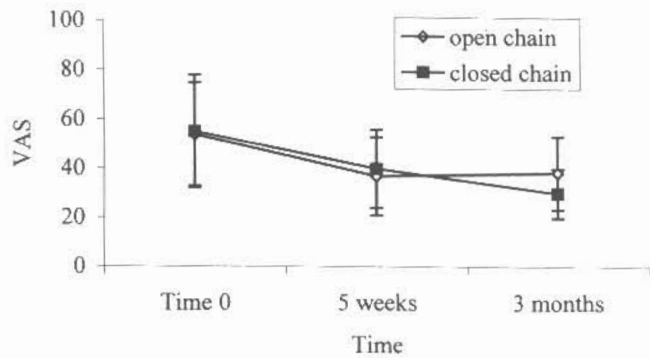

Figure 2. Changes in value of the pain scores, using a 100-mm visual analog scale (VAS), during daily activity for the open and closed kinetic chain groups at the different evaluation periods.

Subjective Assessment

The results of the subjective assessment were obtained by the Kujala score[21] (Fig. 1) and by 18 visual analog scales (Fig. 2). Figure 1 shows that both the closed and the open kinetic chain groups demonstrated a highly significant increase in functionality, obtained by the Kujala score,[21] after 5 weeks ($P = 0.002$ closed kinetic chain group; $P = 0.001$ open kinetic chain group), and at final outcome (3 months) ($P = 0.001$ closed kinetic chain group; $P = 0.0004$ open kinetic chain group). The comparison of the mean scores of the two groups on this scale during the study was never statistically significant ($P > 0.05$).

Statistical analyses revealed a significant improvement in the closed kinetic chain group during this study for the results of the visual analog scale of frequency of locking in the knee joint, experiencing a clicking sensation in the knee joint, pain during the night, and pain during isokinetic testing. This decrease in pain in the closed kinetic chain group under these conditions was found to be as statistically significant for the duration of this study ($P < 0.05$) as for during the treatment period (time 0 to 5 weeks). No significant changes over time for these visual analog scales were observed in the open kinetic chain

TABLE 1
Number of Patients in the Open and Closed Kinetic Chain Groups Who Were Asymptomatic During a Unilateral Squat Test, a Step-Up Test, and a Step-Down Test

Test	Asymptomatic patients					
	Time 0		5 weeks		3 months	
	Open N (%)	Closed N (%)	Open N (%)	Closed N (%)	Open N (%)	Closed N (%)
Unilateral squat	6 (20)	6 (20)	11 (37)	13 (43)	16 (53)	17 (57)
Step-up (45 cm)	11 (37)	8 (27)	23 (77)	18 (60)	22 (73)	22 (73)
Step-down (45 cm)	8 (27)	5 (17)	19 (63)	12 (40)	23 (77)	20 (67)

group ($P > 0.05$). At the 3-month evaluation period, the difference between the closed and open kinetic chain groups was statistically significant ($P = 0.03$ for frequency of locking; $P = 0.041$ for experiencing a clicking sensation; $P = 0.028$ for pain during isokinetic testing; $P = 0.024$ for pain during the night).

Statistical analyses of the visual analog scales of pain during stair-climbing, running, daily activity (Fig. 2), and sports participation; the frequency of pain during the day; a feeling of instability; and the intensity of pain showed a significant improvement during the rehabilitation period in both groups ($P < 0.05$). However, during the follow-up period (5 weeks to 3 months), only the closed kinetic chain group demonstrated a significant reduction of these symptoms. Nevertheless, no significant difference between the closed and open kinetic chain groups was observed at any evaluation period during this study ($P = 0.44$).

The results of the remaining visual analog scales (pain during jumping, walking, sitting with knees bent, and standing up; stiffness of the knee joint; frequency of cracking of the knee joint; and frequency of pain during work) showed a significant improvement over time in both training groups ($P < 0.05$), with no difference between the groups at any evaluation period.

Functional Assessment

The 5-week rehabilitation program was very successful in each group, as determined by significant improvements in functional assessment. The number of patients who were asymptomatic during the unilateral squat test or the step-up and step-down test is presented in Table 1. Comparing time 0 with the evaluation at 5 weeks and at 3 months, the number of asymptomatic patients significantly increased in all three functional tests in both training groups ($P < 0.05$). Statistical analyses demonstrated no significant differences between the number of asymptomatic patients in the closed and open kinetic chain groups at any evaluation period ($P > 0.05$).

Statistical analyses of the triple jump performance revealed a significant increase in jumping distance in the closed kinetic chain group when comparing time 0 with 5 weeks ($P = 0.04$), and when comparing the results of time 0 with the final follow-up ($P = 0.02$). In the open kinetic chain group, this parameter did not demonstrate any statistically significant improvement ($P = 0.13$) over time during this study. However, statistical analyses did not reveal any significant differences between the closed and open kinetic chain groups at any evaluation period during this study ($P = 0.20$).

Changes in value on the 100-mm visual analog scale during the triple-jump test are represented in Figure 3. Improvements over time were statistically significant in both groups. This was true not only between time 0 and 3 months ($P = 0.01$, open and closed kinetic chain), but also between time 0 and 5 weeks ($P = 0.036$, closed kinetic chain; $P = 0.03$, open kinetic chain). Differences between

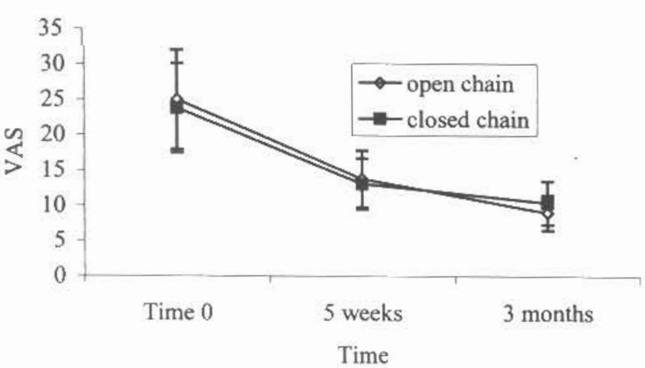

Figure 3. Changes in value of the pain score, using a 100-mm visual analog scale (VAS), during the triple-jump test of the open and closed kinetic chain groups.

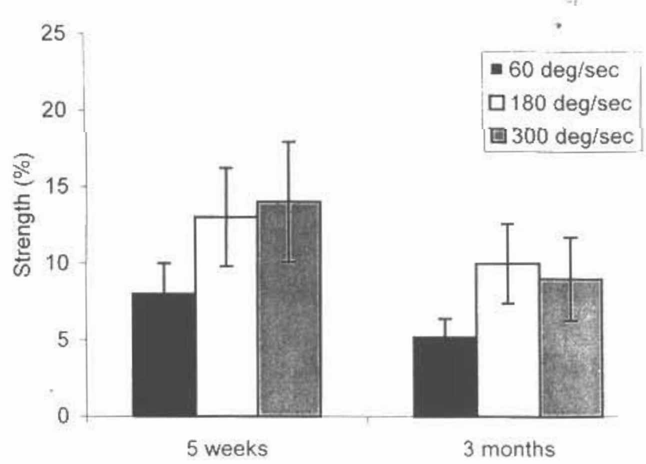

Figure 4. The percentage increase in isokinetic quadriceps muscle strength over time in the closed kinetic chain group ($N = 30$).

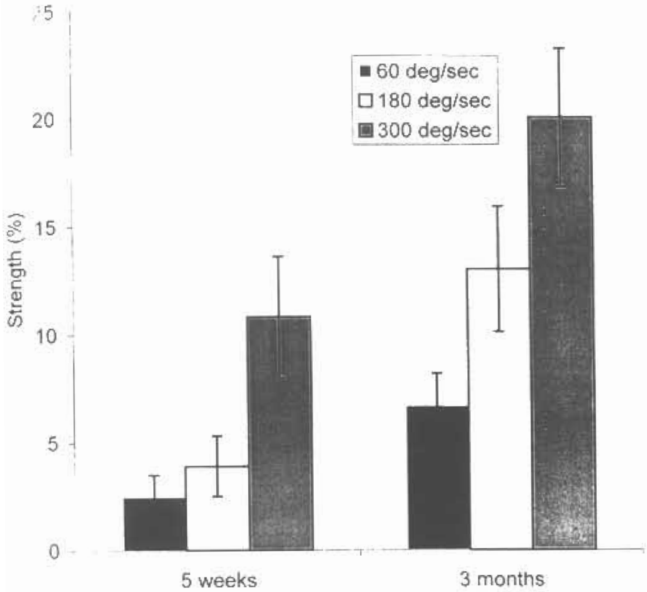

Figure 5. The percentage increase in isokinetic quadriceps muscle strength over time in the open kinetic chain group (N = 30).

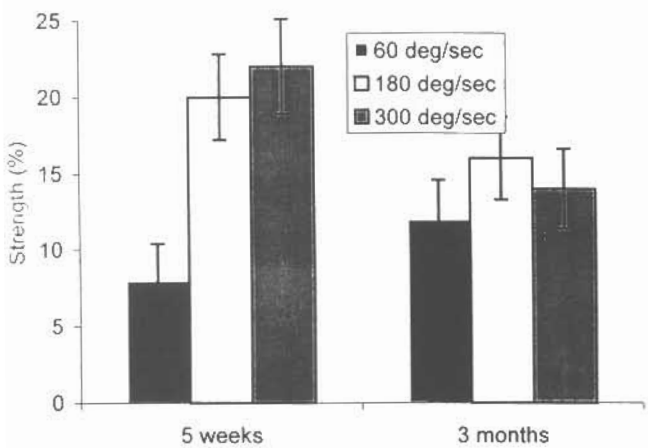

Figure 6. The percentage increase in isokinetic hamstring muscle strength over time in the closed kinetic chain group (N = 30).

the closed and open kinetic chain groups were small and never statistically significant ($P > 0.05$).

Muscle-Strength Measurements

Looking at the changes in isokinetic quadriceps muscle strength compared with the initial quadriceps strength (time 0) in the closed kinetic chain group (Fig. 4), statistical analyses revealed significant increases in the strength at 5 weeks measured at 60 deg/sec ($P = 0.03$), 180 deg/sec ($P = 0.01$), and at 300 deg/sec ($P = 0.01$). However, at the 3-month follow-up, this group showed a statistically nonsignificant ($P > 0.05$) decline in quadriceps muscle strength compared with the 5-week evaluation. As a result, compared with the initial quadriceps muscle strength, the strength at 3 months was found to be significantly elevated at 180 deg/sec ($P = 0.02$) and at 300 deg/sec ($P = 0.02$), but not at 60 deg/sec ($P = 0.13$).

Comparing the postexercise strength (5 weeks) with the initial quadriceps muscle strength in the open kinetic chain group (Fig. 5), a significant increase was found for the measurement only at 300 deg/sec ($P = 0.04$). In contrast with the findings of the closed kinetic chain group, where a (nonsignificant) decrease in quadriceps muscle strength was observed between the 5-week and the 3-month follow-up, the open kinetic chain group demonstrated a nonsignificant increase during this time period ($P = 0.81$ at 60 deg/sec; $P = 0.34$ at 180 deg/sec, and $P = 0.71$ at 300 deg/sec).

Evaluating the results of the open kinetic chain group over the complete duration of the study we observed, in accordance with the findings of the closed kinetic chain group, a significant improvement of quadriceps muscle strength at 180 deg/sec and 300 deg/sec ($P = 0.02$ and 0.01, respectively), but not at 60 deg/sec ($P = 0.45$). Although there was a difference between the groups in observed strength gain during the course of this study, no significant difference between the groups was found at any evaluation period ($P > 0.05$) at the three test velocities.

Similar to the findings in the quadriceps muscle, we observed in this study a significant increase in hamstring muscle strength over time in both rehabilitation groups (Figs. 6 and 7). Comparing preexercise with postexercise (5 weeks) results, the hamstring muscle strength was found to be significantly elevated in both groups at 60 deg/sec ($P = 0.04$ for both closed and open kinetic chain) and at 180 deg/sec ($P = 0.001$, closed kinetic chain; $P = 0.04$, open kinetic chain). At 5 weeks, there was a statistically significant increase in hamstring muscle strength at 300 deg/sec only for the closed kinetic chain group ($P = 0.001$, closed kinetic chain; $P = 0.07$, open kinetic chain).

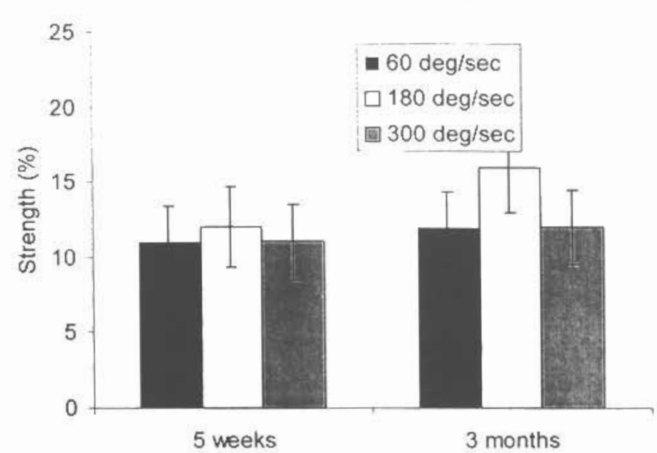

Figure 7. The percentage increase in isokinetic hamstring muscle strength over time in the open kinetic chain group (N = 30).

TABLE 2
Length of the Quadriceps, Hamstring, and Gastrocnemius Muscles of the Rehabilitation Groups at the Different Evaluation Periods

	Rehabilitation group					
	Open kinetic chain			Closed kinetic chain		
Muscle	Time 0 Mean (SD)	5 weeks Mean (SD)	3 months Mean (SD)	Time 0 Mean (SD)	5 weeks Mean (SD)	3 months Mean (SD)
Hamstring	87.8 (15.29)	92.3 (18.72)	93.7 (17.12)	89.8 (14.58)	95.6 (19.72)	94.9 (16.47)
Quadriceps	119.7 (18.66)	126.9 (12.13)	135.8 (16.44)	116.2 (13.52)	129.1 (14.55)	137.5 (14.59)
Gastrocnemius	32 (4.90)	34.8 (4.33)	38 (7.08)	33.6 (6.97)	35 (5.23)	39.7 (4.93)

At final follow-up (3 months), hamstring muscle strength was significantly elevated in both groups, compared with the initial strength, at 60 deg/sec ($P = 0.03$, closed kinetic chain; $P = 0.04$, open kinetic chain) and at 180 deg/sec ($P = 0.02$ for both closed and open kinetic chain). No significant increase in isokinetic hamstring muscle strength was found at the highest test velocity (300 deg/sec) in any of the groups ($P > 0.05$) at final follow-up. No significant differences between the closed kinetic chain group and open kinetic chain groups occurred over time in isokinetic hamstring strength at any test velocity ($P > 0.05$).

Muscle-Length Measurement

Table 2 shows the results of the muscle-length measurements of the quadriceps, hamstring, and gastrocnemius of both groups during this study. Statistics revealed no significant differences between the closed and open kinetic chain groups at any of the evaluation periods ($P > 0.05$). Comparing the muscle length of both knee flexors, the patients in both groups showed a significant increase only when comparing time 0 with 3 months ($P = 0.033$ for the hamstring muscles of the open kinetic chain group, $P = 0.041$ for the hamstring muscles of the closed kinetic chain group, $P = 0.035$ for the gastrocnemius muscle of the open chain group, $P = 0.044$ for the gastrocnemius muscle of the closed kinetic chain group). The length of the quadriceps muscles was found to be significantly increased during the 5-week rehabilitation period ($P = 0.01$, closed kinetic chain group; $P = 0.04$, open kinetic chain group) and during the 3-month follow-up period ($P = 0.03$, closed kinetic chain group; $P = 0.04$, open kinetic chain group).

DISCUSSION

Open and closed kinetic chain exercises have been used by other investigators as a rehabilitation protocol,[6,12,22] but none of these studies compared the results of open versus closed kinetic chain exercises. The results of the present study revealed that both groups demonstrated a significant increase in overall functionality, as measured by the Kujala scale[21] and by the several visual analog scales used in this study. The number of patients who could perform various tests without symptoms increased significantly for both groups. The functional improvement of our patients is in agreement with previous findings reported in the literature of good-to-excellent functional results after a closed[12,22] or an open[6,9] kinetic chain protocol.

Although both groups revealed a significant reduction in the reported pain during various activities, the issue of specificity of training and reports in the literature[10,29] lead one to expect that the closed kinetic chain group would demonstrate more functional benefits from the training program than would the open kinetic chain group. The results of this study reflect this somewhat, indicated by the fact that the results of the performance at a triple-jump test, the frequency of locking in the knee joint, experiencing a clicking sensation in the knee joint, pain during the night, and pain during isokinetic testing, were significantly better in the closed kinetic chain group.

Regarding pain and functionality, the limited differences detected in this study between the two training protocols suggest that the closed kinetic chain exercises are only a little more effective than the open kinetic chain program in reducing pain and increasing functionality. Yet, on the basis of the results of this study, we believe to be unfounded the allegation frequently encountered in the literature that open kinetic chain exercises are absolutely to be avoided in the treatment of patellofemoral pain.

Our strength measurements demonstrated significant strength increases of the quadriceps and hamstring muscles in both rehabilitation groups during this study. These results are consistent with previous findings in the literature concerning strength increases after an open kinetic chain exercise protocol.[3,19] Results in regard to strength parameters after a closed kinetic chain program are, to our knowledge, nonexistent in the literature. A striking finding in this study is the absence of a significant difference in quadriceps or hamstring muscle strength increase between the two exercise protocols. Since the closed kinetic chain exercises contain more eccentric muscle work, and because it is known that eccentric exercise develops more tension in the muscle and thereby obtains a greater training effect,[3] the observation of an equal strength increase in both training groups might be surprising. However, a limitation of this study is that we tested the strength only during an isokinetic open kinetic chain protocol. Since many studies illustrate that the response to weight training is very specific to the training exercise itself,[27] one would expect a greater strength increase in the open kinetic chain group during the open kinetic chain isokinetic test used in this study. Considering that closed kinetic chain exercises contain more eccentric muscle work than open kinetic chain exercises, thereby obtaining greater training effect, and that we used an isokinetic open kinetic chain protocol, the equal strength increase in both training groups observed in this study seems reasonable.

As both training protocols used in this study are mainly designed to increase quadriceps strength, we were astonished that in the two training groups the patients showed a significant increase in hamstring muscle strength. Yet, our results confirm the findings of Campbell and Glenn,[5] who report a significant increase in quadriceps muscle strength as well as hamstring muscle strength as a result of a 7-week open kinetic chain rehabilitation program. In addition, Hewett et al.[14] observed a higher increase in hamstring muscle strength than in quadriceps muscle strength in uninjured female athletes after 6 weeks of functional jumping training. This increase in hamstring muscle strength as a result of the open and closed kinetic chain exercise protocols in this study and in previous studies must be regarded as a striking issue. However, at the time of this study, we were unaware of the effect of this on the patellofemoral joint or on the functionality of the patients.

The association between the strength increase, improvement in functionality, and decrease in pain observed in this study may be of great importance. This relationship between locomotor function and quadriceps muscle strength was already emphasized by Powers et al.,[26] who concluded that strengthening can be considered a very useful treatment option for patients with patellofemoral pain. A recent study by Natri et al.[23] confirms this conclusion by identifying a strong correlation between restoration of quadriceps muscle strength and the long-term final outcome in patients with patellofemoral pain. Apparently, in the latter study the increase in strength was independent of the type of exercises used (open versus closed kinetic chain program). We therefore do not advocate replacing the traditional open kinetic chain exercises by closed kinetic chain exercises, but rather suggest a combined use of these.

Muscle-length measurements in this study reveal significant increases in range of knee motion in both groups. These results are similar to reports of several other investigators who observed a significant increase in knee motion after a 5- to 6-week stretching program.[2,4] Since both exercise protocols in this study used the same stretching program, it was not surprising that no significant difference between the two groups was observed. These observations, however, cannot be used to determine the influence of muscle length on the functional outcome. A limitation in this study is the absence of a control group of patellofemoral patients who received no treatment; however, witholding treatment from patients with patellofemoral pain was considered to be unethical. Since pain was already chronic at the beginning of this study (mean, 15.1 months), we believe it is improbable that any significant natural improvement would have occurred during this study. Therefore, we are relatively certain that the significant improvements observed in this study are a result of the exercise programs.

It cannot be excluded that if more subjects had participated in this study some results would have been different. We believe that further research is required before definite conclusions can be drawn.

CONCLUSIONS

This study showed that there was a significant improvement in strength and functionality as a result of both closed and open kinetic chain exercise programs. The few significant differences between the training groups supports the premise that closed kinetic chain exercises are more effective in the treatment of patellofemoral pain than the conventional open kinetic chain protocol. As a result of this study, we now use both closed and open kinetic chain exercises in the nonoperative treatment protocol for patients with patellofemoral pain.

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