Clinical Perspective

Open Versus Closed Kinetic Chain Exercise: Issues in Rehabilitation After Anterior Cruciate Ligament Reconstructive Surgery

What has been called "closed kinetic chain" (CKC) exercise has become popular in the last 5 to 10 years for use after anterior cruciate ligament (ACL) reconstructive surgery. Closed kinetic chain exercises appear to have gained popularity over more traditionally used open kinetic chain (OKC) exercises because many clinicians believe that CKC exercises are safer and more functional. These clinicians also contend that CKC exercise is equally effective as OKC exercise in restoring quadriceps femoris muscle force production following ACL reconstructive surgery. The purpose of this clinical perspective is to examine the evidence concerning OKC and CKC training after ACL reconstructive surgery with regard to these issues and discuss how physical therapists can best apply this knowledge in clinical practice. Based on the review of data, it does not appear that clinicians should completely abandon more traditional OKC exercises and replace them with CKC exercises in postoperative ACL reconstruction rehabilitation programs. Both types of exercise apparently can be modified to minimize (1) the risk of applying excessive strain on the ACL graft and (2) the risk of excessive patellofemoral joint stress. Depending on the functional goals of the patient, both OKC and CKC exercises may be appropriate for simulating functional activities. When improvement in quadriceps femoris muscle function is an essential treatment goal, therapists may need to combine OKC exercises with CKC exercises to provide optimal training stimuli. Suggestions for further research are discussed. [Fitzgerald GK. Open versus closed kinetic chain exercise: issues in rehabilitation after anterior cruciate ligament reconstructive surgery. *Phys Ther.* 1997;77:1747–1754.]

Key Words: *Exercise, general; Ligaments; Rehabilitation; Surgery.*

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Some orthopedic surgeons and physical therapists have advocated the sole use of closed kinetic chain (CKC) exercises after anterior cruciate ligament (ACL) reconstructive surgery and have abandoned the use of open kinetic chain (OKC) exercises.[1,2] There has been much debate regarding appropriate definitions for CKC and OKC exercises and whether these terms adequately describe therapeutic exercise procedures.[3] For the purpose of this report, I will describe these exercises as I believe they are commonly used. Open kinetic chain exercises are typically non-weight bearing, with movement occurring at a single joint. The distal segment is free to move, and the resistance is usually applied to the distal segment. An example would be a knee extension exercise, performed in a sitting position with resistance applied to the distal segment. Closed kinetic chain exercises are typically weight bearing. Movement at several joints is required to complete the movement, the distal segment is usually fixed to a supporting surface, and the resistance may be applied both proximally and distally. An example of a CKC exercise would be a squat.

Three prevalent assumptions apparently have led to the popularity of CKC exercises over OKC exercises. The first assumption is that CKC exercises are believed to be safer than OKC exercises because they place less strain on the ACL graft and are thus less likely to produce patellofemoral pain.[4,5] A second assumption is that CKC exercises are believed to be more functional than OKC exercises,[4] although advocates may mean that they mimic functional activities. Finally, it is believed that CKC exercises are equally effective as OKC exercises in improving quadriceps femoris muscle force production. Therefore, because CKC exercises are assumed to be safer and to lead to greater function, they should replace OKC exercises for this type of training.[1,6]

Although these ideas are popular, the evidence to support them is limited and, in some respects, these ideas appear to be based more on personal opinion than on data. There is some evidence to refute these ideas.[7–11] I believe that there is a need to reconsider the underlying assumptions that influence clinical reasoning with regard to CKC and OKC exercises. This should be done by examining the available evidence and by identifying what evidence is still needed. This clinical perspective will examine the literature concerning OKC and CKC exercises after ACL reconstructive surgery. Issues related to safety, function, and treatment effectiveness will be considered. Application of present knowledge to clinical practice and suggestions for study will also be discussed.

Safety Issues Concerning Open and Closed Kinetic Chain Exercises

Excessive Anterior Cruciate Ligament Graft Strain

Some authors[1,6] believe that the use of OKC exercise for improving force production of the quadriceps femoris muscle places excessive strain on an ACL graft. A study by Henning et al[6] is frequently cited to support this belief. Henning et al measured the strain in the partially torn ACLs of two subjects. An elongation gauge was inserted into the anterior bundle of the distal 1 cm of the ACL. The strain of the ACL was measured during a Lachman's test with 36.3 kg (80 lb) of force, using a hand-held load cell that was applied to the proximal tibia with a web belt. A 0.045-in Kirschner wire was used to attach the load cell to the tibial tubercle. A "sensitive beam" extended from the load cell to the anterior aspect of the patella. Anterior displacement of the tibia was measured with respect to the patella. This procedure was used only for the Lachman's test. The anterior tibial displacement measured during the Lachman's test with 36.3 kg of force was considered to be 100 units of ACL elongation. The ACL strain was then recorded during activities that were said to use a CKC (ie, crutch walking, single-leg half squat, walking, jogging, and stationary cycling) and during activities that were said to use an OKC (ie, knee extension against a 9.1-kg [20-lb] resistance through 22° to 0° and 35° to 0° of motion and holding the 9.1-kg load at 45° of knee flexion). A weighted boot was used. The ACL strain data during these activities were expressed as a percentage of the strain from the 36.3-kg Lachman's test and are reported in Table 1. Henning et al concluded that quadriceps femoris muscle exercises following ACL repair should be done using activities such as cycling and partial squatting to avoid placing excessive strain on the healing ligament. They discouraged the use of OKC knee extension exercises through the full range of motion during the first year following ACL injury and reconstruction.

Although the study by Henning et al[6] is frequently cited to support the use of CKC exercises after ACL reconstruction, there are a number of methodological factors

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Table 1.
Estimated Anterior Cruciate Ligament Strain During Various Activities Reported by Henning et al[6] as a Percentage of the Strain That Occurred During a 36.3-kg (80-lb) Lachman's Test

Activity	Percentage of Strain
Crutch walking, 22.7 kg (50 lb) weight bearing	7[a]
Single-leg half squat	21[a]
Walking	36[a]
Jogging on floor	89[a]
Stationary cycling	7[a]
Leg extension, 22° to 0°	79,[a] 12[b]
Leg extension, 36° to 0°	7[a]
Isometric contraction of quadriceps femoris muscles against resistance of 9.1 kg (20 lb) at 45° of flexion	50[a]
Isometric contraction of quadriceps femoris muscles against resistance of 9.1 kg (20 lb) at 0° of flexion	107,[a] 87[b]
Isometric contraction of quadriceps femoris muscles against resistance of 9.1 kg (20 lb) at 22° of flexion	121,[a] 62[b]

[a] Subject 1 (female).
[b] Subject 2 (male).

that should limit the conclusions that can be made from this study. The measurements were taken from two subjects with partially torn ACLs. The strain behavior from an intact ACL graft most likely is different than that of a partially torn ACL. Therefore, inferences made concerning ACL strain during OKC and CKC activities from the data obtained by Henning et al may not apply to the strain on an intact ACL graft. Table 1 indicates that although two subjects participated in the study, strain data were collected on only one subject during several activities. During the activities in which data were collected on both subjects, there appears to be a wide range of variability in the strain measurements between the two subjects. The large degree of variability in the measurements, combined with such a small sample, reduces the meaningfulness of any conclusions made from these measurements.

Yack et al[12] examined the amount of anterior tibial displacement during resisted knee extension (OKC exercise) and during a parallel squat (CKC exercise) in 11 subjects with ACL deficiency. Measurements of anterior tibial displacement were taken on both the involved and noninvolved limbs. Yack et al reported increases in anterior tibial translation of the involved limb during OKC knee extension, compared with the partial squat activity through joint excursions of 66 to 10 degrees of knee flexion. There were no differences in anterior tibial translation between exercises for the noninvolved limb. The authors stated that although they did not measure the strain on the ACL, their results suggested that weight-bearing exercises would result in less ACL strain than non–weight-bearing quadriceps femoris muscle exercises. Although these results may describe differences in anterior tibial translation when the ACL is not present, they cannot describe the strain on an ACL graft after surgery during OKC and CKC exercises. There may be greater anterior tibial shear forces during OKC knee extension movements compared with CKC squats, but do these forces necessarily result in greater strain on the ACL graft? That is, is the difference in anterior shear force great enough to result in a meaningful difference in strain between these exercises? This question can be answered only by measuring the strain on the ACL graft during OKC and CKC exercises. There have been no studies, thus far, that have done this.

Recently, Beynnon and colleagues[7,8] and Fleming et al[9] measured the strain on the intact ACL in human subjects during OKC and CKC exercises commonly used in quadriceps femoris muscle exercise programs. A strain gauge was inserted in the anterior bundle of the ACL in each subject during arthroscopic surgery for a partial meniscectomy. The OKC exercises consisted of full-range leg extension with and without a 45-N boot and isometric contractions of the quadriceps femoris muscles against 35 N·m of resistance applied at the distal tibia at varying angles of knee flexion.[7–9] The CKC exercises consisted of a squatting exercise with resistance from an elastic cord[8] and a squatting exercise without the added resistance.[9] Anterior cruciate ligament strain was reported as a percentage of the measured strain from a 200-N anterior tibial translational force. The results are listed in Table 2. There was no difference in ACL strain characteristics between OKC and CKC exercises, in general. According to the data they reported, zero strain was measured during isometric contractions of the quadriceps femoris muscles against 35 N·m of resistance at knee flexion angles of 90 and 60 degrees.

Fleming et al[9] stated that if an ACL graft is properly placed during a reconstruction, it would be reasonable to assume that differences in strain on the graft may not be meaningful during OKC and CKC exercises. During the early 1980s, ACL graft placement during reconstructive surgery was performed in a manner that sometimes resulted in excessive increases in strain on the graft as the knee was moved from flexion to end-range extension.[13,14] The combination of this type of graft placement with OKC exercises to improve quadriceps femoris muscle force production sometimes resulted in failure of the graft. Therefore, surgeons placed restrictions on postoperative exercises. Graft placement techniques currently being used allow the knee to be moved from flexion to end-range extension without subjecting the graft to harmful levels of strain.[15] Fleming et al[9] argue

Table 2.
Anterior Cruciate Ligament Strain Values During Open and Closed Kinetic Chain Exercises Reported by Beynnon and Colleagues[7,8] and Fleming et al[9]

Activity	Percentage of Strain[a]
Knee extension[b]	2.8[7]
Knee extension with 45-N boot[b]	3.8[7]
Isometric knee extension, 30 N·m, 15° of knee flexion[b]	4.4[7]
Isometric knee extension, 30 N·m, 30° of knee flexion[b]	2.0[7]
Isometric knee extension, 30 N·m, 60° of knee flexion[b]	0.0[7]
Isometric leg extension, 30 N·m, 90° of knee flexion[b]	0.0[7]
Squatting, without resistance[c]	3.6[9]
Squatting, with resistance[c]	4.1[9]

[a] Anterior cruciate ligament strain was reported as a percentage of the calculated strain from a 200-N anterior tibial translational force.
[b] Open kinematic chain exercise.
[c] Closed kinematic chain exercise.

that with this improved anatomical placement of the ACL graft, the graft may respond more like the intact ACL during OKC and CKC exercises. Therefore, they argue, both types of exercise could be done safely.

Another consideration for planning these exercise procedures after ACL reconstructive surgery is that the presence of some strain on the healing graft may actually be beneficial. Histological studies have indicated that applying some tension on healing ligaments will enhance the remodeling stage of healing.[16] Both the ligament and the ligament attachment sites had greater tensile strength when they were subjected to tensile loads during healing. The absence of strain on ligaments, even those that have not been injured, has been shown to have harmful effects.[17] Given the implications of these studies, it may be an error in clinical reasoning to select CKC exercises for quadriceps femoris muscle training because they reduce strain on the healing graft and to reject OKC exercises for quadriceps femoris muscle training because they increase strain on the healing graft. The presence of strain during exercise may actually be beneficial, but this is a purely theoretical argument. The level that distinguishes beneficial strain from harmful strain during healing has not been established, and therapists should proceed with caution. Being cautious, however, does not mean that therapists should adopt an "all or none" approach to therapeutic exercise, particularly when they may be excluding a treatment that may be beneficial. The results of Beynnon and colleagues[7,8] and Fleming et al[9] seem to indicate that therapists could use both CKC and OKC exercises without placing harmful levels of strain on an ACL graft. If therapists have concerns about minimizing ACL graft strain during OKC knee extension exercise, based on the data from Beynnon and colleagues presented in Table 2, perhaps all they would need to do is restrict the range of joint excursion from 90 to 30 degrees of flexion.

Patellofemoral Joint Stress

Proponents of CKC exercises often claim that an additional benefit of these exercises is that they are less likely to cause patellofemoral pain because they subject the patellofemoral joint to less joint stress than do OKC exercises.[1] Hungerford and Lennox[18] and more recently Steinkamp et al[10] have suggested that the angle through which OKC and CKC exercises are performed may be the determining factor regarding patellofemoral joint stress.

Steinkamp et al[10] described a mathematical model for estimating patellofemoral joint stress, based on limb segment lengths for the thigh and shank, the external knee moment created by a resistance load applied during knee extension and leg press exercises, and the patellofemoral joint contact areas at various angles of knee flexion. The Figure illustrates the estimated patellofemoral joint stress during an OKC exercise and a CKC exercise with comparable loads of resistance, based on the model of Steinkamp et al.[10] The graph illustrates that patellofemoral joint stress can be minimized or increased during both types of exercise, depending on the range of motion through which the exercise is performed. For example, during the OKC exercise as the knee is moved from 90 degrees of flexion to an extended position, the patellofemoral joint stress is steadily increased. In contrast, during the CKC exercise as the knee is moved from an extended position to 90 degrees of flexion, patellofemoral joint stress is steadily increased. Therefore, if therapists want their patients to do knee extension exercises, they can be done without inducing excessive patellofemoral joint stress by limiting the joint excursion from 90 degrees to approximately 45 degrees. If therapists prefer to use CKC exercises, they may need to limit the joint excursion from full extension to approximately 45 degrees of flexion. Moving into greater positions of flexion during CKC exercises would result in patellofemoral joint stress comparable to that observed during OKC leg extensions that approach full knee extension.

Conclusions Regarding Safety Issues

The studies discussed do not support the assumption that CKC exercises are safer than OKC exercises after ACL reconstruction. In theory, both types of exercise can be performed in ways that do not place excessive strain on an intact ligament, and research is needed to

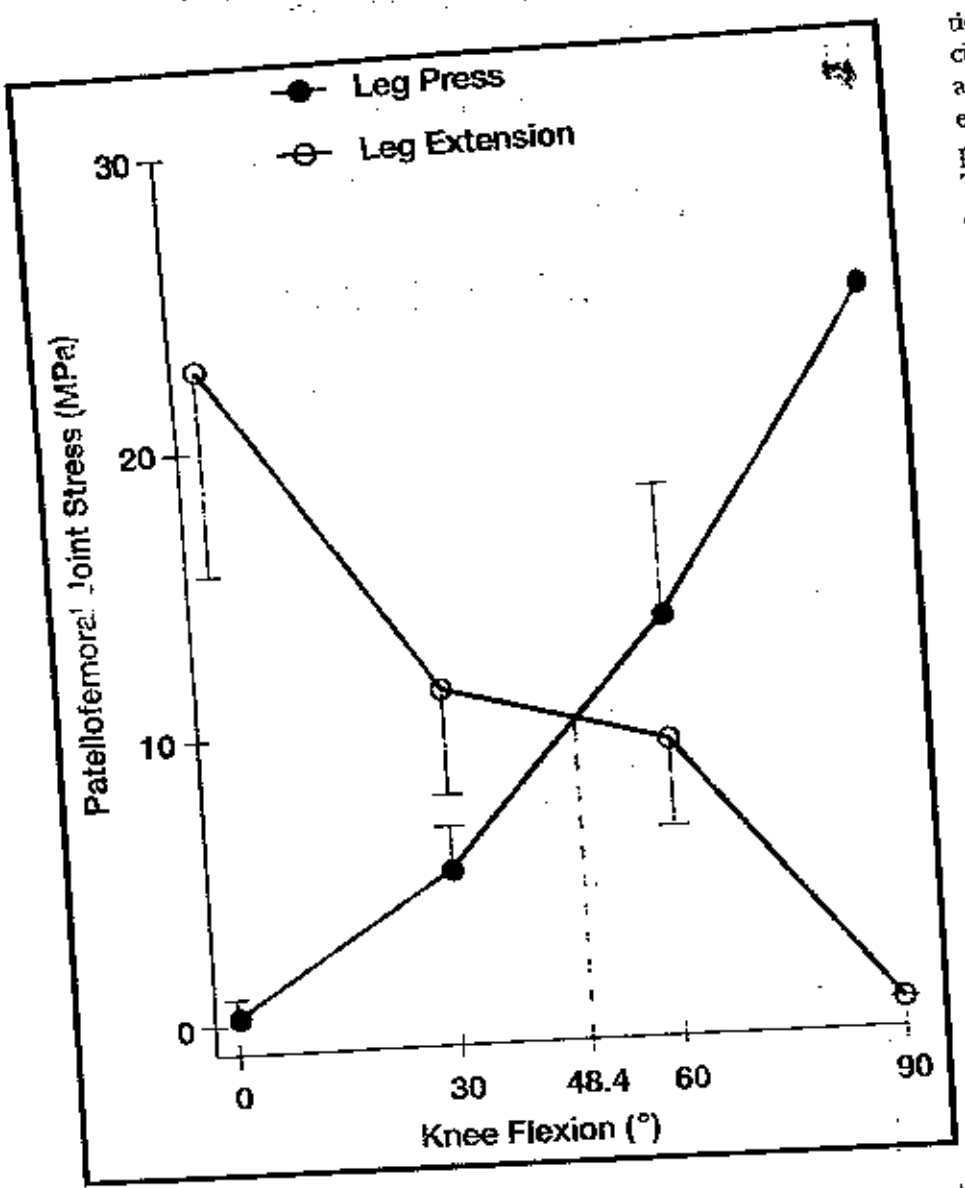

Figure.
Means and standard deviations of patellofemoral joint stress at four flexion angles. Reprinted with permission from Steinkamp et al.[10]

determine whether this is also true for an ACL graft. The presence of strain during exercise may actually enhance healing of a graft. Research is needed to determine the level of stress that distinguishes beneficial from harmful levels of strain on a healing graft. Excessive patellofemoral joint stress can be avoided in either type of exercise by restricting the range of motion through which the exercise is performed. To ensure safety during exercise, therapists need to consider the knee joint excursion through which either OKC or CKC quadriceps femoris muscle exercises are performed.

Functional Issues Related to Open and Closed Kinetic Chain Exercises

There is a popular opinion that CKC exercises tend to promote function more than do OKC exercises because CKC exercises involve primarily weight-bearing activities.[1,2,4,19] I believe that most clinicians would agree that there are advantages to using weight-bearing exercises in a lower-extremity muscle performance training program. These exercises would require coordinated activity from several muscle groups to complete a task, much like what could be required during many functional tasks. Sensory input may be provided during weight-bearing exercises in a manner similar to many functional tasks.

The following quotation illustrates the problem with making global statements concerning the functional utility of CKC exercises: "Since the foot is usually in contact with the ground, activities that make use of this closed system are more functional."[4(p100)] I do not find it difficult to list many examples where functional activities do not occur with the foot in contact with the ground. During sprinting, for example, the foot is on the ground for the relatively small percentage of time required to complete the gait cycle.[20] During the swing phase, the quadriceps femoris muscles may be required to produce a large amount of OKC hip flexion and knee extension torque to maximize the stride length. This functional activity includes both OKC and CKC elements. Training programs that promote both OKC and CKC knee extension may actually do more to improve function in this circumstance than simply using one type of exercise. Evidence for my argument is lacking, but so is evidence for the global statement that I quoted.

Some exercise devices, because they allow for lower-extremity CKC exercise, are said to be more functional than devices that use OKC training. The various machines used to simulate stair climbing are an example. Do these devices, however, really mimic stair climbing as it is performed during everyday living? During real stair climbing, the stairs themselves are fixed and the individual controls the rate of movement to ascend and descend the stairs. The stairs on the climbing machines move in a downward direction as force is applied to them, and the machine controls the rate of movement. With actual stair climbing, the person's center of gravity

moves forward and upward. Would these simulators alter the movement characteristics of the lower extremities during the exercise to the extent that they do not resemble those encountered during real stair climbing? Real stair climbing also has an OKC component (ie, when the non–weight-bearing limb is elevated and placed on the next step to meet the center of gravity). Exercise on some stair-climbing machines may not require this component. On other stair-climbing machines, the individual has to assist in elevating the non–weight-bearing limb, but the foot may remain in contact with the step at all times, eliminating the need to reestablish proper foot placement. Would eliminating the requirement for reestablishing foot placement reduce the usefulness of stair-climbing machines for simulating the functional task of stair climbing? Most importantly, if our patients exercise on stair-climbing machines, do they restore their ability to climb stairs more effectively? There are no data to suggest that these devices help persons following ACL reconstruction.

The point here is not that the stair-climbing machines are undesirable exercise devices. There may be benefits obtained from exercising on these devices. A device, however, should not be considered to be more functional simply because it includes weight bearing. A device should be considered to provide a functional benefit if it improves the patient's ability to perform tasks under conditions that are likely to be encountered during daily activities, not merely because the concept underlying its design seems appropriate.

There is no evidence to date that has demonstrated that patients have superior functional outcomes when either CKC or OKC exercises are used. The conclusion that CKC exercise is more functional has been made purely on the basis of presumptive arguments. If claims are to be made concerning the functional superiority of CKC exercises over OKC exercises, then it should be demonstrated in controlled clinical trials that compare their effectiveness in restoring function. At present, common sense would indicate that how well an exercise simulates function may have more to do with the functional goals of the patient than with the type of kinetic chain used during the exercise, but even this assumption lacks data to support it. Therapists may decide that either an OKC exercise or a CKC exercise may be best in simulating functional activity, depending on their patients' goals.

Quadriceps Femoris Muscle Training

Proponents of CKC exercises believe that these exercises are superior to OKC exercises for quadriceps femoris muscle training after ACL reconstruction because these exercises are safer and equally effective in restoring quadriceps femoris muscle force production. The studies of Bynum et al[1] and Henning et al[6] are commonly cited to support these notions. Neither Bynum et al nor Henning et al, however, actually measured changes in quadriceps femoris muscle force production after training between patients who performed OKC exercises and patients who performed CKC exercises during rehabilitation after ACL reconstructive surgery.

Table 3.
Quadriceps Femoris Muscle Isometric Torque Output Following a 4-Week Training Program Reported by Snyder-Mackler et al[11]

Training Program	Percentage of Maximal Voluntary Contraction[a]
High-intensity electrical stimulation	70
High- and low-intensity electrical stimulation	70
Low-intensity electrical stimulation	51
Volitional closed kinetic chain exercise	57

[a] Quadriceps femoris muscle isometric torque values for the injured limb expressed as a percentage of the maximum quadriceps femoris muscle isometric torque values for the noninjured limb.

Recently, Snyder-Mackler et al[11] compared changes in maximum voluntary isometric quadriceps femoris muscle torque between subjects who performed CKC exercises and subjects who performed combined CKC and OKC exercises after a 4-week training program. A second purpose of the study was to examine the effectiveness of high-intensity electrical stimulation combined with voluntary exercise compared with voluntary exercise alone. Subjects were randomly assigned to one of four experimental groups. All four groups performed a high-intensity CKC exercise program. In addition to the CKC exercises, one group received high-intensity electrical stimulation during OKC contractions of the quadriceps femoris muscles. During the high-intensity electrical stimulation, the contractions of the quadriceps femoris muscles were performed isometrically at a knee flexion angle of 60 degrees. This position was chosen, in part, in an attempt to minimize strain on the ACL graft. A second group received high-intensity electrical stimulation combined with low-intensity electrical stimulation. A third group received only low-intensity electrical stimulation, in addition to the CKC exercises. The fourth group performed only the CKC exercises and did not receive electrical stimulation or perform OKC contractions of the quadriceps femoris muscles.

The results obtained for the four groups are shown in Table 3. The groups that performed the OKC contractions with high-intensity electrical stimulation demonstrated greater increases in quadriceps femoris muscle torque compared with the other two groups. The increase in quadriceps femoris muscle torque was also found to be correlated with improved kinematics during

the stance phase of gait. According to Snyder-Mackler et al,[11] subjects exhibited a reduced excursion of tibiofemoral joint flexion and extension during stance, compared with what is usually observed in noninjured subjects, prior to training. Following training, the subjects receiving high-intensity electrical stimulation exhibited tibiofemoral joint flexion and extension patterns similar to those of noninjured subjects. Subjects who did not receive high-intensity electrical stimulation did not exhibit changes in tibiofemoral joint flexion and extension patterns, compared with pretraining values. There was no evidence that any subjects in the groups performing the OKC contractions damaged the grafts. Snyder-Mackler et al[11] concluded that if a meaningful strength deficit exists following ACL reconstructive surgery, CKC exercises alone may not provide enough of a training stimulus to correct the problem. They recommended that judicious use of OKC contractions combined with CKC exercises may be the best alternative for restoring function of the quadriceps femoris muscles. The term "judicious use" implies that therapists may want their patients to perform these contractions in a position of greater knee flexion if the therapists are concerned about stressing the graft (Lynn Snyder-Mackler, ScD, PT; personal communication; 1997).

Because the two groups that demonstrated the greatest improvement in quadriceps femoris muscle torque also received high-intensity electrical stimulation in the study by Snyder-Mackler et al,[11] conclusions concerning the effectiveness of OKC exercise versus CKC exercise are limited. The superior torque gains may have had more to do with the high-intensity electrical stimulation treatment than with the fact that these groups performed OKC exercises. The study demonstrated, however, that high-intensity isometric contractions of the quadriceps femoris muscles can be performed safely when they are performed with the knee in a 60-degree position of flexion.

Perhaps we may expect OKC contractions of the quadriceps femoris muscles to provide a greater training stimulus because there is less chance of substitution by other muscle groups in resisting the applied load. During some CKC exercises, such as the squat or stair climbing, muscles about the hip and ankle may also contribute to the forces necessary to overcome the resistance.[5,21] For example, during the squat, the hamstring muscles contract to extend the hip and the gastrocnemius muscles contract to plantar flex the ankle against the resistance. These muscles work in coordination with the quadriceps femoris muscles to overcome the resistance. Therefore, if the quadriceps femoris muscles are weak, these other muscle groups may substitute for the lack of force being generated by the quadriceps femoris muscles. Further study is needed to determine how exercise programs that combine OKC and CKC exercises, using voluntary contractions, compare with those that use only CKC exercises in improving quadriceps femoris muscle force production after ACL reconstructive surgery. These studies should also help to determine whether augmenting OKC exercises with high-intensity electrical stimulation is an essential component of the training program.

Conclusions

There is currently much debate regarding whether CKC exercises or OKC exercises are the "best" approach after ACL reconstructive surgery. I believe that therapists should be cautious about using this "either one or the other" thought process when planning therapeutic exercise programs. The "best" exercises are those that maximize patients' ability to achieve their goals while minimizing their risk of further injury. The present literature concerning the application of OKC and CKC exercise programs raises as many questions about issues of safety and treatment as it provides answers. In my view, there is a place for both types of exercises in knee rehabilitation programs.

With regard to safety issues, it appears that both OKC and CKC exercises can be applied in a manner that minimizes the risk of excessive graft strain and patellofemoral compression, by using different knee joint motion excursions for each type of exercise. When OKC knee extensions are performed, therapists may want to limit the knee joint motion excursions to more flexed positions. During CKC lower-extremity exercises, therapists may want to limit knee joint motions to more extended positions. What needs to be learned, however, is how these modifications will affect outcome. Will treatment effectiveness for restoring quadriceps femoris muscle force be maintained or enhanced with these modifications? There is no point in using a treatment modification for the sake of safety if the desired treatment effect cannot be achieved with the modification. If quadriceps femoris muscle force can be restored using these modifications, will greater functional activity levels be achieved with less incidence of patellofemoral pain and ACL graft failure? These questions warrant further clinical investigation.

Research is also needed in determining how OKC and CKC exercises can be combined in a program to maximize the level of functional outcome. What is the best way to match the type of OKC or CKC exercise with the type of functional activities performed by the patient? Should our decision-making schemes be based on how well an exercise simulates the movement and muscle activity characteristics of the target functional activity, or should our strategy be based on how well an exercise can overcome a physical impairment that is believed to be

contributing to the functional deficit? Probably both of these issues should be considered in selecting the best exercises for our treatment programs. However, these are theoretical issues. We currently lack data, and clinicians need to be wary about adopting too strong a view on the issues until there is more evidence. We should recognize that both OKC and CKC exercises may have their place in ACL rehabilitation programs, and we should strive to determine how we can best combine these exercises to achieve optimal treatment outcomes.

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