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Authors
Sachs, Raymond A
Daniel, Dale M
Ston, Mary Lou
et al.

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Patellofemoral problems after anterior cruciate ligament reconstruction*

RAYMOND A. SACHS,† MD, DALE M. DANIEL, MD, MARY LOU STONE, RPT, AND RICHARD F. GARFEIN

From the Department of Orthopedics, Kaiser Permanente Medical Center, San Diego, California

ABSTRACT

Between 1982 and 1986, 126 patients who had undergone ACL reconstruction were followed in a prospective manner. One year follow-up statistics were reviewed for the presence of 13 different complications. The most prevalent complications were quadriceps weakness, flexion contracture, and patellofemoral pain. Quadriceps weakness (strength less than 80% of the normal side) was present in 65% of patients and correlated positively with flexion contracture, patellar irritability, and ACL reconstructions using patellar tendon grafts. Flexion contracture of 5° or more was present in 24% of patients and correlated positively with increased age and patellar irritability. Patellofemoral pain was present in 19% of patients and correlated positively with flexion contracture.

Clinical relevance: The three most common complications of knee ligament surgery are shown to be strongly interrelated. It is likely that a causal relationship is present in which flexion contracture causes patellofemoral irritability, and that both of these factors, alone or in combination, result in quadriceps weakness. If this theory is correct, then it is crucial that postoperative rehabilitation programs place a major emphasis on the avoidance of flexion contracture.

In 1982, a review in our clinic of ACL reconstruction patients revealed a high incidence of symptoms and signs consistent with patellofemoral problems. A review of 36 patients with normal patellofemoral joints at the time of surgery revealed that 1 year later, only one-third had a normal patellofemoral clinical examination. Of the remaining patients, one-third had anterior knee crepitance but no pain, while the other third not only had anterior knee crepitance but also had anterior knee pain. In pursuit of a better understanding of patellofemoral problems after ACL reconstruction surgery, we performed a literature review, sent a questionnaire to 50 prominent knee surgeons, and formalized a prospective study to evaluate patellofemoral function after knee ligament surgery.

MATERIALS AND METHODS

Literature review

A MEDLINE search was performed for all articles from 1965 to 1986, reporting on ACL reconstruction or complications of ACL surgery. This review yielded 68 articles. Each article was analyzed for the reported rate of each of 13 different complications. The result in each of these 13 categories was tabulated and an average rate obtained, where possible, for each complication.

Surgeon questionnaire

Fifty prominent knee surgeons who had published in the field of ACL reconstruction were sent a questionnaire with a cover letter. Each surgeon was asked to list his complication rate in each of 13 different categories, relating to his last 100 cases of ligament surgery. Forty of the 50 surgeons replied and their results were tabulated and averaged for each complication.

Clinical study

A protocol knee ligament evaluation form was developed at the San Diego Kaiser Foundation Hospital in 1982. The evaluation consisted of a patient questionnaire, the physical examination, anterior-posterior ligament laxity tests with the KT-1000, and performance tests. The clinical tests that became most important in analyzing patellofemoral problems were knee extension measurements, patellar crepitance, and patellar irritability.

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† Address correspondence and reprint requests to: Raymond A. Sachs, MD, 250 Travelodge Drive, El Cajon, CA 92020.

Knee extension was evaluated with the patient prone on a firm examining table with both lower limbs hanging off the end of the table. If the patient has a unilateral flexion contracture, one knee will be bent and one heel will be higher than the other (Fig. 1). The angle thus formed between the two lower limb segments is the degree of flexion contracture. Since this angle is typically small (1° to 5°), the flexion contracture may be determined with accuracy by first measuring the difference in heel heights (HHD), then dividing by the lower limb segment length (LLSL, the distance from the knee joint line to the sole of the foot), and computing the arctangent of the result (Fig. 2).

For adult patients of average height, a quick estimate of flexion contracture may be used. Consider a patient 181 cm (72 inches) tall with a measured HHD of 1 cm. The LLSL can be determined with accuracy by using the formula, LLSL = height × 28%.[3] The LLSL for this patient is 181 × 0.28, or approximately 51 cm. HHD/LLSL = 1/51 = approximately 0.0196, the arctangent of which is about 1.1°. Thus, for most adults, 1 cm of heel height difference equals about 1° of flexion contracture. This relationship is shown in Table 1. We have found heel height difference in centimeters to be a reproducible and reasonably accurate measure of flexion contracture.

Patellar crepitance was estimated by having the patient actively extend his knee through a 90° arc while the examiner's hand was positioned directly on top of the patella. Crepitance was subjectively estimated on a scale of 0 to 3.

The tests for patellar irritability were performed with the patient supine on an examining table. The examiner first palpated the medial and lateral patellar facets. Next, the patient's limb was supported on a bolster in 20° to 30° of knee flexion. The patella was firmly pressed into the trochlear groove while the patient was asked to actively extend his knee. The patient's reaction to both of these maneuvers was noted and a subjective rating of patellofemoral pain was made on a scale of 0 to 3.

The performance tests were isokinetic flexion and extension strength testing and the one leg hop for distance. Isokinetic strength testing was performed with a Cybex machine. To assess normal left-right strength symmetry, peak torque generated with knee extension and flexion at 60 deg/sec was measured using a standardized testing protocol including a warm-up and instrument familiarization.

The one leg hop for distance is designed to test both strength and confidence in the tested leg. Standing on one leg, the subject hops as far as possible, landing on the same leg (Fig. 3). Three separate hops are performed for each leg and the average distance is compared.

In a previous study by Daniel et al.,[4] 47 male and 47 female volunteers aged 15 to 45 years and without history of lower limb problems were tested on the Cybex. The strength index was expressed as a ratio of the peak torque of the weaker leg divided by the peak torque of the stronger leg, multiplied by 100. The mean quadriceps index was 90.5% and the mean hamstring index was 89%. In 94% of the volunteers, the quadriceps index was equal to or greater than 80%. Based on this testing, quadriceps strength symmetry and hamstring strength symmetry equal to or greater than 80% was judged to be satisfactory. In this same study, 100 normal subjects had a hop index (lesser average distance divided by greater average distance, times 100) equal to or greater than 90%. Thus, a hop symmetry equal to or greater than 90% was judged to be satisfactory. Both of these standards were used in the present study.

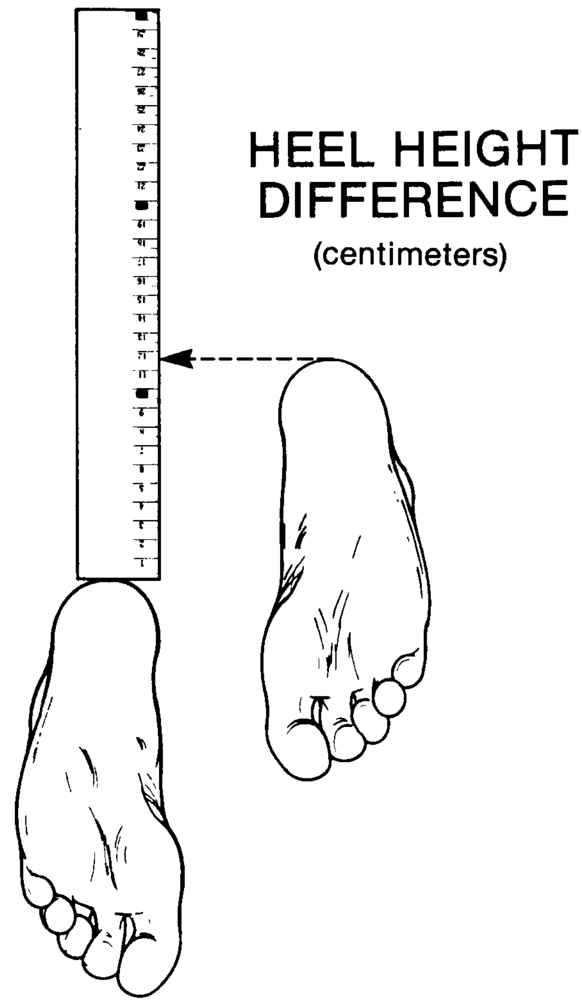

Figure 1. Heel height difference is measured in centimeters with the patient prone. As a quick estimate, each centimeter of heel height difference is equal to one degree of knee flexion contracture.

The evaluation form, which included all of the measurements described, was completed prior to knee surgery and at 1, 2, and 3 years after surgery. At surgery, a standard form was used to record the operative findings and the surgical procedure. Data on 133 patients were entered into a computer for tabulation and analysis and correlation matrices were generated from the entered data. In seven cases, the data were incomplete and these cases were excluded.

The present report is based on the 1 year postoperative evaluation of 126 unilateral ACL injured patients operated

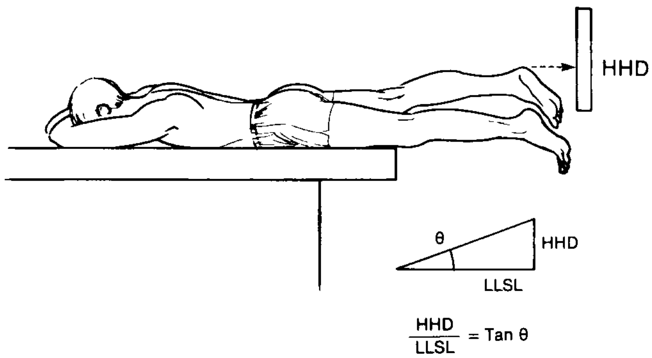

Figure 2. The patient's knee flexion contracture (angle θ) is derived from the following calculations: The ratio of the heel height difference (HHD) to the lower limb segment length (LLSL) equals the tangent of θ; computation of the arctangent gives the angle θ, or the knee flexion contracture: $\theta = \text{Tan}^{-1}$ (HHD/LLSL).

TABLE 1
Flexion contracture (degrees)

Patient height (inches)	Heel height difference (cm)					
	2.5	5	7.5	10	12.5	15
62	3.3	6.6	9.8	13	16.1	19.1
66	3.1	6.2	9.2	12.2	15.1	18.0
70	2.9	5.8	8.7	11.5	14.3	17.0
74	2.8	5.5	8.2	10.9	3.6	16.1
78	2.6	5.2	7.8	10.4	12.9	15.4

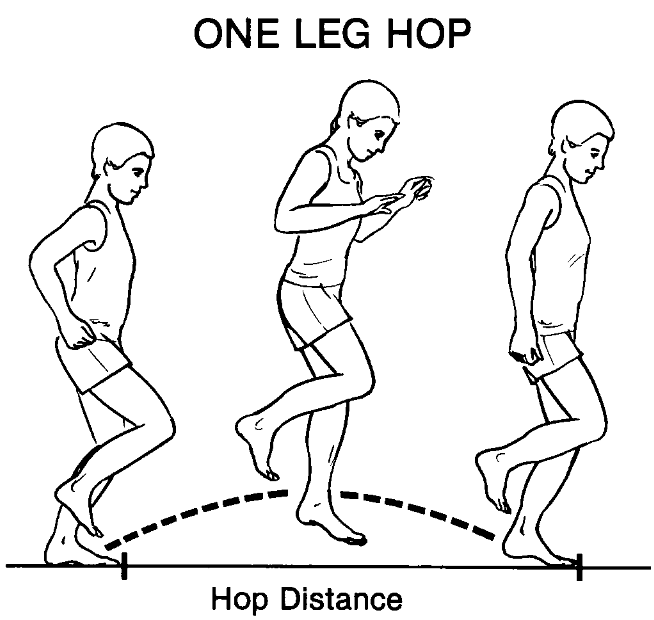

Figure 3. A standing one leg hop, or broad jump, is performed three times on each limb. The average distance on the operated side divided by the average distance on the normal side is called the hop index.

on between 1982 and 1986. In all cases, the ligament surgery was confined to an intraarticular reconstruction of the ACL. The graft source was the patellar tendon, a hamstring tendon, or the iliotibial band. The graft orientation was over-the-top or through the femur. In cases performed since 1985, graft isometry was measured using the MEDmetric tension isometer (MEDmetric Corp., San Diego, CA).

The rehabilitation protocol during the study was relatively constant, consisting of cast immobilization in 30° of flexion for 3 weeks, followed by a range of motion brace with a 30° extension stop for an additional 3 to 5 weeks. Crutches with touch-down weightbearing were commonly used for 6 to 8 weeks. While immobilized, patients were advised to do thigh cocontraction exercises. After 6 to 8 weeks, the program included bicycling, swimming, and limited arc isotonic exercises. Running exercises were initiated at 6 to 9 months. Terminal extension exercises were not performed during the first postoperative year.

RESULTS

The literature, the surgeon's poll, and our own data were analyzed for the incidence of 13 different complications (Table 2). For each source, the three most prevalent complications were quadriceps weakness, flexion contracture, and patellofemoral pain.

The analysis of our own group of 126 patients revealed that the following factors were interrelated: age, flexion contracture, patellar irritability, quadriceps strength index, hamstring strength index, hop index, and graft source (Table 3).

Age

Patients ranged in age from 16 to 47 years with a mean of 24.5 years. Age was positively correlated with flexion contracture. The mean age of the patients with full extension was 23.1 years, while the mean age of those patients with flexion contracture greater than 5° was 28.7 years. Of the patients with full extension, 68% were 24 years or younger.

TABLE 2
Complication rates (%)

	Literature	Poll	Series	References
Quadriceps weakness	47	23	65[a]	1,6,10–12
Flexion contracture	32	24	24[b]	1,2,5–9,12,13
Patellofemoral pain	32	12	19	5–7,10,13
Additional complications[c]				
Effusion	13	2.5	16	
Knee pain		10	3	
Manipulation	4	4	5	
Superficial infection	4	1	0.75	
Deep infection	1.6	0.5	0.75	
Skin necrosis	2	0.5	0.75	
Reflex sympathetic dystrophy	0	0.75	0	
Graft site morbidity	1	0.75	0	
Deep vein thrombosis	3.5	1	0.75	

[a] Quadriceps index <80%.
[b] Flexion contracture ≥5°.
[c] Not specifically related to this study.

TABLE 3
Interrelated factors

Factor	Positive correlations	Negative correlations	r Value	P value
Age	Flexion contracture		0.26	0.002
		Hop index	−0.14	0.053
Flexion contracture	Age		0.26	0.002
	Patellar irritability		0.17	0.029
		Hop index	−0.20	0.012
		Quadriceps index	−0.14	0.059
Patellar irritability	Flexion contracture		0.17	0.029
		Quadriceps index	−0.23	0.004
		Hamstring index	−0.20	0.012
		Hop index	−0.16	0.036
Quadriceps index	Hamstring index		0.30	0.001
	Hop index		0.59	0.001
		Flexion contracture	−0.14	0.059
		Patellar irritability	−0.23	0.004
Hamstring index	Quadriceps index		0.30	0.001
	Hop index		0.31	0.001
		Patellar irritability	−0.20	0.012
Hop index	Quadriceps index		0.59	0.001
	Hamstring index		0.31	0.001
		Age	−0.15	0.053
		Flexion contracture	−0.20	0.012
		Patellar irritability	−0.16	0.036
Patellar tendon graft source	Flexion contracture		0.21	0.023
		Quadriceps index	−0.27	0.014

Flexion contracture

Flexion contractures ranged from 0° to 24° with a mean of 3.3°. Flexion contracture had a positive correlation with patellar irritability and a negative correlation with hop index. A negative correlation was also found between flexion contracture and quadriceps strength index. This correlation could be demonstrated by comparing patients with flexion contracture to patients with a normal quadriceps strength index of greater than 80% (Table 4).

Patellar irritability

Twenty-four patients (19%) had patellar irritability on their physical examination 1 year after reconstruction. Patellar irritability was found to have negative correlations with quadriceps index, hamstring index, and hop index. Thus, all three measurements of strength were adversely affected by the presence of patellar irritability.

The possible additive effect of flexion contracture and patellar irritability in regard to quadriceps strength was evaluated. Each factor was found to diminish quadriceps strength to a degree that was statistically significant. As shown in Table 5, the presence of both factors in the same knee resulted in a greater decrease of quadriceps strength than that produced by either factor alone.

TABLE 4
Flexion contracture vs. normal quadriceps strength

Flexion contracture (deg)	No. of patients	Quad index >80%
0	46	17 (37%)
1–5	56	14 (25%)
>5	32	4 (12%)

TABLE 5
Patellar irritability (IRR) and flexion contracture (FC) vs. mean quadriceps strength

	Mean quad strength (%)	Difference (%)
IRR 0	68.0	13.3
IRR >0	54.7	
FC 0	72.8	10.4
FC >0	62.4	
IRR 0 and FC 0	74.2	23.9
IRR >0 and FC >0	50.3	

Quadriceps, hamstring, and hop indexes

Mean quadriceps index was 66.2%, and 42 patients (33.3%) attained a quadriceps index greater than or equal to 80%. The mean hamstring index was 88.1%, and 85 patients (67.4%) achieved a hamstring index greater than or equal to 80%. Mean hop index was 78.1% and 43 patients (34%) achieved a hop index greater than or equal to 90%.

These factors can be considered together. All three were found to correlate strongly with one another ($P = 0.001$). Thus, in general, a patient with a weak knee showed both quadriceps and hamstring weakness, and this was well demonstrated functionally by a diminished hop index. Conversely, a strong leg tested well for both muscle groups and the patient performed well on the hop test.

Graft source

No difference in hamstring strength was found 1 year after surgery when hamstring and patellar tendon ACL reconstructions were compared. Thus, harvesting the semitendinosus and gracilis tendons had no measurable effect on hamstring strength. Graft source did appear to affect quadriceps strength, however. At 1 year, mean quadriceps strength was 71.2% with hamstring grafts versus 60.8% with patellar tendon grafts, a significant difference ($P = 0.021$).

An attempt was made to determine whether or not this quadriceps weakness was a direct effect of harvesting one-third of the patellar tendon or whether the weakness was secondary to other factors such as flexion contracture and patellar irritability. To ensure elimination of these variables, a "pure" group of 32 patients who had no flexion contracture and no patellar irritability were analyzed. Of these 32 patients, 17 had undergone a patellar tendon reconstruction while 15 had undergone a hamstring reconstruction. Mean quadriceps strength was 71.5% in the patellar tendon group and 82.5% in the hamstring group, a strongly significant difference. Thus, it appears that graft source alone influences quadriceps strength at 1 year after reconstruction.

DISCUSSION

The ultimate goal of ACL reconstruction is to produce not only a stable knee but also a strong and functional knee. This study has shown that age, graft source, flexion contracture, and patellar irritability all significantly influence the quality of the end result. The study further suggests that the hop index can be a useful measurement of the patient's overall leg strength.

It is tempting to postulate a chain of events linking these factors:

• Flexion contracture, which causes increased patellofemoral contact forces, results in patellar irritability.

• Patellar irritability, flexion contracture, and patellar tendon graft source all result in diminished quadriceps strength. Each of these factors alone causes decreased quadriceps strength; in combination it appears that their effects are additive.

• Diminished quadriceps strength leads to diminished function, as measured by the hop index.

If this theory is correct, then it seems crucial that any postoperative rehabilitation program place a major emphasis on the avoidance of flexion contracture. In our study group, 46% of patients who had no flexion contracture and no patellar irritability had a normal quadriceps index at 1 year, regardless of graft source. Conversely, of those patients who demonstrated both flexion contracture and patellar irritability, only 6% had a normal quadriceps index (Table 6).

TABLE 6
Patellar irritability (IRR) and flexion contracture (FC) vs. normal quadriceps strength

	N	Quad index >80%
IRR 0 and FC 0	33	15 (46%)
IRR >0 and FC >0	18	1 (6%)

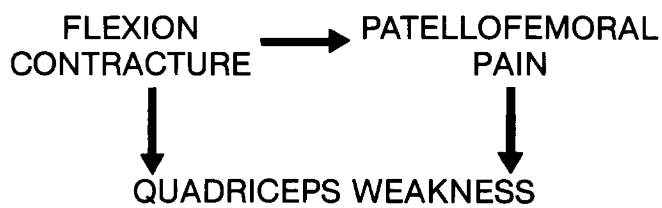

Figure 4. Proposed causal relationship linking the three most common complications of knee ligament surgery.

CONCLUSIONS

This study began in an attempt to determine the etiology of patellofemoral pain after ACL reconstruction. The prospective data collected over the past 5 years has revealed that the three most common complications of the knee ligament surgery—patellofemoral pain, flexion contracture, and quadriceps weakness—are intimately related (Fig. 4).

A causal relationship cannot be proven without further study. We feel it is likely, however, that elimination of flexion contracture would produce a chain reaction resulting in diminished patellofemoral pain and increased quadriceps strength. While we recognize the fact that a successful ACL reconstruction is a multifactorial event, we strongly recommend that knee rehabilitation programs place a high priority on the maintenance of full knee extension.

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DISCUSSION

William A. Grana, MD, Oklahoma City, OK: The purpose of this paper is to achieve a better understanding of results—specifically, patellofemoral problems—following ACL reconstructive surgery. The materials included a literature review, a questionnaire analysis, and a prospective study of the patellofemoral function after knee ligament surgery. Based on this data, the most common complications following ACL reconstruction included patellofemoral pain, flexion contracture, and quadriceps weakness.

As a discussor, let me say that it was a pleasure to review this paper because of its superb organization, careful methods, and the analysis provided, but I do not think we would expect anything else from Dale Daniel and his associates. The results indicate that the age of the patient, the graft source, flexion contracture, and patellar irritability significantly influenced the quality of the end result. Furthermore, since age and graft source may not always be controlled, the avoidance of flexion contracture becomes the cornerstone of obtaining a good result.

I have no quarrel with the materials, methods, results, or the analysis of those results. (In addition, the authors have described an interesting and promising way of looking at functional results.) I do have the following questions: First, based on this information, what graft source do the authors currently use as their preferred graft, all other variables being equal? Secondly, should the problem patient who has a varus knee with recurvatum and external rotatory laxity be treated differently than others? Have the author looked at these patients separately from others in the group, and as a corollary to that, how much extension is enough? Is a small amount of flexion contracture, from 0° to 5° desirable, particularly in this problem group? And finally, what role, if any, does CPM or electrical stimulation play in the routine management of these patients?

Authors' Reply: We use different grafts for different situations. In our studies, the hamstring tendon graft source gave us a greater and more reliable range of motion but at the expense of an increased failure rate. The patellar tendon graft source gave us increased stability but greater complications in terms of a higher degree of flexion contracture. Presently, for the young athletic patient, we are using the patellar tendon graft source, and we choose to address the problem of flexion contracture by casting in extension. For older patients, and patients with degenerative arthritis, we use the safer hamstring graft.

In terms of how much extension is enough, I strongly feel that the patient must have full extension. I do not believe that a small degree of flexion contracture is desirable. The difficult patient, the one who has hyperextension, I have no answer for. Certainly, if you have a patient who has posterlateral instablilty and 10° of recurvatum, you have to be a brave man to immobilize the knee at minus 10°.

Lastly, as to the use of CPM, I believe it is a two-edged sword. I think it can even be detrimental in obtaining extension, although it may be helpful in obtaining flexion. I doubt that it has as much a role in postoperative ACL rehabilitation as some people may think.