REHABILITATION PROTOCOL AFTER ISOLATED POSTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Ricardo de Paula Leite Cury[1], Henry Dan Kiyomoto[2], Gustavo Fogolin Rosal[3], Flávio Fernandes Bryk[4], Victor Marques de Oliveira[5], Osmar Pedro Arbix de Camargo[6]

ABSTRACT

To create a rehabilitation protocol following reconstruction of the posterior cruciate ligament (PCL), through a literature review. The literature review was conducted in the Medline and Embase databases, to search for data on biomechanical concepts and analyses relating to the posterior cruciate ligament of the knee. The search strategy was set up using the following rules: problem or injury in association with anatomical location terms; or surgical intervention procedure in association with rehabilitation terms. We began the process in this manner and subsequently introduced restrictions on certain terms to improve the search specificity. To design the protocol, a table was created for better data assessment, based on the time that elapsed between surgery and the start of physiotherapy. A rehabilitation protocol was created to improve weight-bearing control in the initial weeks after surgery, with the aid of a knee brace. Our aim was to achieve gains in total range of motion of the knee, which should be attained by the third month, thereby avoiding contractures resulting from the tissue healing process. Strengthening exercises and sensory-motor training were guided accordingly, thus avoiding overload on the graft and respecting the healing phases. The protocol proposed through this review was based on the current evidence relating to this subject.

Keywords – Posterior Cruciate Ligament; Knee; Rehabilitation

INTRODUCTION

There is a lack of biomechanical, histological and clinical studies on knee rehabilitation following posterior cruciate ligament (PCL) injury, in relation both to cases treated conservatively and to cases that underwent reconstruction. The existing studies are often based on aspects of the integration and rehabilitation of the anterior cruciate ligament (ACL), transposed to the PCL. The aim of the present study was to review the points presented in the current literature and, together with tacit knowledge of the last few years at our clinic, to put forward a rehabilitation protocol.

METHODS

A search in the literature was conducted using the Medline database through the PubMed website and using the Embase database through the Patient, Intervention, Comparison and Outcome (PICO) strategy. The investigation was divided into search strategies that emphasized range of motion and therapeutic exercises, as described below.

Regarding range of motion (ROM): Surgery, Reconstruction and Posterior cruciate ligament were combined and the terms Posteromedial corner, Posterolateral corner, Arthroplasty, Prosthesis and Total knee

1 – Instructing Professor and Head of the Knee Surgery Group, Department of Orthopedics and Traumatology, School of Medical Sciences, Santa Casa de Misericórdia de São Paulo (SCMSP), São Paulo, SP, Brazil.
2 – Professor in the Physiotherapy Course, São Camilo University Center and São Judas Tadeu University; Researcher in the Biomechanics Laboratory, São Judas Tadeu University, São Paulo, SP, Brazil.
3 – Researcher in the Biomechanics Laboratory, São Judas Tadeu University, São Paulo, SP, Brazil.
4 – Professor in the Musculoskeletal Physiotherapy Specialization Course and Physiotherapist in the Knee and Sports Traumatology Groups, Santa Casa de Misericórdia de São Paulo, São Paulo, SP, Brazil.
5 – Instructing Professor in the Knee Surgery Group, Department of Orthopedics and Traumatology, School of Medical Sciences, Santa Casa de Misericórdia de São Paulo (SCMSP), São Paulo, SP, Brazil.
6 – Adjunct Professor in the Knee Surgery Group, Department of Orthopedics and Traumatology, School of Medical Sciences, Santa Casa de Misericórdia de São Paulo (SCMSP), São Paulo, SP, Brazil.

Work performed in the Knee Surgery Group, Department of Orthopedics and Traumatology, School of Medical Sciences, Santa Casa de Misericórdia de São Paulo (SCMSP), São Paulo, SP, Brazil.

Correspondence: Rua Barata Ribeiro 380/64, Bela Vista, 01308-000 São Paulo, SP, Brazil. E-mail: ricacury@uol.com.br

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replacement were used to clean up the search for related articles. In addition, the Mesh terms Rehabilitation and Range of motion were also combined in an attempt to only retrieve articles relating to ROM. In this manner, 33 articles were identified. Of these 11 reported the ROM and/or showed programs for ROM gain.

Regarding exercise programs: Posterior cruciate ligament [Mesh] was combined with Physical therapy modalities [Mesh], Rehabilitation [Mesh], Exercise [Mesh], Exercise therapy [Mesh] and Exercise test [Mesh] as a strategy, and 19 articles were identified. Of these, six had the objective of analyzing the rehabilitation protocol.

In addition, because few in vivo studies were available, we also used a strategy with greater sensitivity, through analyzing in vitro biomechanical studies and mathematical modeling studies on knee-related exercises.

From using a filter for meta-analyses or randomized controlled clinical trials, only one study was identified, and this did not cover all aspects of rehabilitation. Thus, the present review (Table 1) was conducted mainly on basic science studies and on cadaver models, because of the few randomized controlled clinical trials found. The protocol was constructed in a spreadsheet with a format that accompanied the variable of postoperative time. Thus, the protocol was made to be easy to view and to consult (Annex 1).

RESULTS

The protocol presented shows the period of early release for weight-bearing over the first weeks, done partially through use of two crutches and a long immobilizer locked into extension.

Passive mobilization for improving ROM should be done early on; for this, we recommend that progressive gain should be envisaged, with the parameters of 70° of flexion in the fourth week and 90° in the sixth week. Following this, full ROM needs to be achieved by the third month in order to avoid contractures resulting from the tissue healing process. Note that active flexion movement of the knee should be delayed for two months.

The post-surgical reconstruction period for the PCL may be accompanied by pain. In this case, analgesia provided through electrotherapeutic means is beneficial for the rehabilitation process, with regard to the patient's comfort. Cryotherapy should be used whenever the knee presents conditions of pain or edema.

The greatest limitation of physiotherapy in the

Table 1 – Review with systematized search of the literature.

	Brace in extension	Weight-bearing	ROM	OKC	CKC	Hamstrings
Fanelli *et al* (1994)[27]	6th week	Tolerance	0-90° without time period	0-70°	X	X
Irrgang & Fitzgerald (2000)[25]	6th to 8th week	Tolerance	0-90° for 6 to 8 weeks	60°, 1st to 3rd week	45°, 4th to 6th week	Avoid, without defined date
Stähelin *et al* (2001)[15]	6th week	Tolerance	0-90°	X	X	X
Allen *et al* (2002)[28]	4th week	Tolerance	X	X	4th to 6th week	16th week
Margheritini (2002)[18]	6th week	Partial until 6th or 8th week	Progressive and slow	X	6th to 8th week	Avoid, but without defined date
Bottoni & Parr (2003)[11]	Release after achieving good quadriceps control	Progressive after 8th week	0 to 70° from 4 to 6 weeks	X	X	X
Noyes *et al* (2003)[16]	6th week	Partial initially and full after 6th week	3°-0°-120°	X	0-70°	8th week
Wang *et al* (2003)[8]	6th week	Tolerance	Not specified	X	X	6th week
Chen *et al* (2003)[7]	6th week	Tolerance	0-60° up to 6th week and 0-90° up to 8th week	X	6th week	X
Faustino (2003)[17]	6th week	Tolerance	Without stipulated limit	X	12th week	
MacGillivray *et al* (2006)[12]	4th week	Partial	0 to 90°	X	X	X
Fanelli *et al* (2010)[21]	4th to 6th week	Without loading until 6th, partial from 7th to 10th and full in 11th week	3rd to 6th week without stipulated ROM	X	X	X
Fanelli (2008)[3]	3rd to 6th week	Without loading until 6th, partial from 7th to 9th and full in 10th week	Progressive start in 4th week	0-45° in 11th week	0-45° in 11th week	Start in 24th week
McAllister & Hussain (2010)[20]	3rd week	Without loading until 3rd-6th, partial between 3rd and 6th and full in 6th week	Start between 3rd and 6th weeks	X	X	X
Quelard *et al* (2010)[19]	6th week	Without loading until 10th day, partial between 11th day and 6th week and full after 6th week	0-60° until 6th week, 0-95° until 8th week and 0-120° after 8th week	2nd week	6th week 0-60°	16th week
Fanelli *et al* (2010)[21]	5th week	Without loading until 5th week, partial until 10th week and full after 10th week	5th to 10th weeks	X	11th week	X
Edson *et al* (2010)[22]	5th week	Without loading until 5th week, partial until 10th week and full after 10th week	5th to 10th weeks	After 5th week	After 10th week 0-60°	24th week

patient rehabilitation process relates to strengthening exercises. In our protocol, we delay open kinetic chain (OKC) exercises for the knee flexors until the eighth week after the operation, while closed kinetic chain (CKC) and OKC exercises for the extensors remain in the second week.

Sensory-motor work should start together with the release to perform CKC exercises for the extensors, and the progression from stable ground surfaces to unstable surfaces should be done by around the fourth month, along with stressing for anteroposterior, side-to-side and rotational displacement, respectively. Over this period, we begin the process of plyometric training, which is reserved for the population of athletes.

The time taken for non-athletic individuals to be released for general activities is around six months, with a further two months for sports activities at competitive level.

DISCUSSION

The rehabilitation process for PCL injuries is assessed as a complementary but essential point within functional recovery of the knee[1]. Rehabilitation protocols prioritize protection of the reconstructed ligament, so as to avoid excessive stress on the graft during the rehabilitation until the graft has become integrated[2]. However, it is not known with any certainty what the safe tensions would be and how much provocation can be allowed during rehabilitation exercises[3].

Little is known on the structural modifications of grafts after ligament reconstruction. Bosch and Kasperczyk[4] studied the histochemical and biochemical characteristics of grafts from the central third of the patellar tendon for ACL reconstruction, in sheep, with the aim of understanding the integration process. They found a necrotic phase with diminution of the resistance to stress particularly in the eighth week after reconstruction. It is noteworthy that graft necrosis continued to be seen until the 104th week, i.e. two years after the reconstruction.

Moreover, it is a difficult task to determine the stress that the ligaments are subjected to during passive movement of the knee in weight-bearing and muscle force activities and whether these are prejudicial to the graft. Direct measurement methods such as placement of load cells (measurement devices) in the ligament are difficult to do in vivo. Thus, studies on cadavers and indirect biomechanical methods such as inverse dynamics are the methods most used.

Points relating to ROM

To avoid loss of ROM, Irrgang and Harner[5] divided the care relating to reconstructed knees into three phases: before the surgery, the focus should be on elimination of edema and pain and restoration of ROM; during the operation, ROM seems to be closely related to the positioning of the bone tunnels and to the surgical technique; after the surgery, early mobilization and gains in mobility are recommended, with extension restored after two to three weeks and flexion achieved by the third month[6].

Restrictions relating to the limits on knee flexion gains are discussed in the literature, with divergences between the rehabilitation protocols presented. Some authors have prioritized limiting the range of angles to between 0 and 60º[7-10], 0 and 70º[11], 0 and 90º[12-15] or 0 and 120º[16], or without any stimulated limit[17] or according to the patient's tolerance[18]. Quelard et al[19] recommended a gradual protocol for gaining passive mobility of the knee, such that a range of 0-60° would be achieved in the first six weeks, 0-90° from the sixth to the eighth week and 0-120° from the eighth week onwards.

Some studies have used a slower protocol and have not included passive mobilization of the knee in the first weeks. McAllister and Hussain[20] started the protocol between the third and sixth weeks, Fanelli et al[21] between the fifth and tenth weeks, Fanelli[3] in the fourth week and Edson et al[22] in the fifth week.

The criteria of ROM progression are not discussed in the protocols that we found, and there is no biomechanical explanation to explain why passive gain of movement is limited. The protocols used in the literature seem to be based on personal clinical experience[22].

In situ studies on PCL tensions[23] have demonstrated that with increasing degree of passive flexion of the knee, there is also an increase in the tension in the PCL. Moreover, the varus stress and posterior shear stress in the tibia may also generate increased force on the PCL[24].

Because of this evidence, caution is needed in relation to gains in passive knee ROM. On the other hand, delayed gain in movement may have consequences such as restriction of joint ROM and functional loss.

One of the practical procedures used by many professionals during rehabilitation is to stabilize the tibia using constant anterior pressure on the posterior region of the leg, in order to avoid excessive tension on the ligament. Decreased tension on the PCL through anteriorization of the tibia has been demonstrated in studies on cadavers[24] and was advocated by Irrgang and Fitzgerald[25] in their rehabilitation protocol.

Our protocol restricts the gain in passive ROM to 70º for four weeks and progresses to 90º for another two weeks. After the sixth week, gains in passive ROM are progressive, according to the patient's tolerance, but we maintain the passive anteriorization force applied to the tibia until the tenth week.

Release for weight-bearing (walking)

Early release for weight-bearing in isolated reconstruction of the PCL is a common practice among the rehabilitation protocols cited in the literature[11,12,16], but there is no consensus regarding how much this could be done without causing deleterious effects to the graft undergoing healing. Many protocols[7,15,17] favor early weight-bearing according to the patient's tolerance. In other words, the introduction of weight-bearing may be completed in the first weeks of reconstruction.

Through a study with a mathematical model, Shelburne and Pandy[26] demonstrated that because of the forces exerted on the knee during weight-bearing, the tibia presents a tendency towards anterior shearing in relation to the femur, which theoretically would not overload the PCL.

Bosch and Kasperczyk[4] conducted an experiment on sheep and found that movement and early weight-bearing did not cause ruptures and did not increase the length of the graft. Corroborating this concept, Toutoungi et al[2] found that the effect of axial compression tended to diminish the femorotibial shearing and consequently the stresses generated on the central ligaments.

In the study by Noyes and Barber-Westin[6], which involved PCL reconstruction, weight-bearing was introduced progressively, with a protective orthosis locked in extension for four weeks, until full weight-bearing was reached around the fifth week. However, other studies are divergent. Some authors have recommended that weight-bearing should be introduced according to the patient's tolerance and should be started in the first week[7,8,15,17,20,27,28], while one study restricted weight-bearing until the sixth week[16] and others until the eighth week[11,18].

In some protocols, weight-bearing is not recommended during the first days after reconstruction. Quelard et al[19] used a protocol without weight-bearing over the first 10 days, progressing to partial weight-bearing on the 11th day, which continued until the fifth week, with full weight-bearing from the sixth week onwards. McAllister and Hussain[20] did not used weight-bearing for three weeks and progressed to partial weight-bearing in the fourth and fifth weeks and full weight-bearing in the sixth week.

Edson et al[22] did not use weight-bearing for five weeks and progressed to partial weight-bearing in the sixth week and full weight-bearing in the 10th week. Other authors have used different protocols (Table 1); however, all of them used a protective orthosis locked in extension, in association with weight-bearing.

Based on the studies cited above, our group feels increasingly secure in recommending partial weight-bearing, with evolution to full weight-bearing according to the patient's tolerance, for isolated PCL injuries.

Muscle strengthening

There have been divergences of opinion regarding the use of OKC or CKC exercises as rehabilitation options for the process of muscle strengthening, in relation to efficacy of strength gains, control over knee muscles and stress on ligaments. There is a tendency towards using CKC exercises at the start of protocols, with complementation using OKC exercises at the more advanced phases[29-34]. CKC exercises generate axial compression forces on the joint, which diminishes the shearing forces on the knee, as well as leading to simultaneous contraction of the quadriceps and hamstrings, which are desirable in the initial phase of rehabilitation.

In the rehabilitation protocols cited in previous studies[7,11,17], OKC and CKC exercises were introduced in an arbitrary manner, without backing from any studies quantifying the tensions in the PCL or their consequences in relation to ligament laxity during the rehabilitation process. Quelard et al[19] recommended that OKC exercises for strengthening the quadriceps should be started from the second week. Some studies have suggested starting these exercises in the first three weeks[7-9,11], while others have introduced them only between the fourth and sixth weeks[10,13,14,22]. Fanelli[3] only started quadriceps strengthening with OKC exercises in the 11th week, at angles of 0-45°.

Certain protective angle ranges have been recommended for OKC quadriceps strengthening exercises. Ranges of 0 to 60º have been used[9,13,14], while other authors have recommended that this strengthening should be done from 0 to 70º[27].

Dürselen et al[23] demonstrated on cadavers, and other authors[2,33,35] through mathematical models, that in OKC exercises, the quadriceps muscle might diminish the stress on the PCL, especially at the end of the knee extension. Thus, these were the preferred exercises at the start of the rehabilitation process.

One proviso needs to be made in relation to OKC exercises for the quadriceps and their implications in post-reconstruction rehabilitation of the PLC. By considering only the protection angles in relation to PCL grafts, excessive stress may be placed on the femoropatellar joint and may consequently cause lesions in the cartilage coating this joint[36]. Therefore, the safe angle for the neoligament is between 0 and 70º[25], and protection for the femoropatellar joint involves angles from 45 to 90º[36]. Thus, with the aim of protecting the graft and the femoropatellar joint, our group uses angles from 45 to 70º to stimulate the quadriceps. Since this only leaves a small range of motion, we undertake the OKC exercises in isometric form at multiple angles within this safety range. The aim of OKC exercises in the initial phase is not related to gains in strength, resistance or muscle power, but to recruitment of the maximum number of muscle fibers. Thus, we undertake OKC exercises by associating the patient's maximum voluntary contraction with neuromuscular electrostimulation, with the aim of combating the arthrogenic inhibition that is present in diseased knees[37].

The rehabilitation protocols that we found introduced CKC exercises for quadriceps strengthening at different times during the rehabilitation protocol. These times included the fourth[9,10], sixth[19,27], eighth[11,14], tenth[22], eleventh [3,21] and twelfth weeks[17].

Regarding the protection angles, three variants were found in our investigation. Some authors started with mini-squats from 0 to 45º[3,25], others introduced CKC exercised at angles from 0 to 70º[16] and yet others[19,22] started with 0 to 60°.

In vivo studies[38-40] analyzing the length of the native PCL through measurements made using magnetic resonance imaging have demonstrated that CKC exercises increased the length of the two bands of the PCL at greater flexion angles. However, this type of measurement is unable to define the amount of tension generated in the PCL during active rehabilitation exercises. Therefore, only direct measurements by means of load cells would be capable of defining these tensions, but the methodology of this procedure makes it very difficult to assess the PCL.

CKC exercises are safe in relation to anterior shearing forces on the tibia[26] and should be performed carefully in the initial phase of the rehabilitation process following PCL surgery. The factors that may have an influence on the stresses in the cruciate ligaments are the forces generated by muscle contractions, such as co-contractions and ground reaction forces[32].

Shelburne and Pandy[26] demonstrated that from 10º of flexion onwards, in CKC exercises, the PCL presents increased tension, even though the peak stress occurs at around 80º of flexion.

In our protocol, CKC exercises are started in the second week and are initially performed in situations of controlled overload. We use exercises on stable surfaces, such as leg press exercises, mini-squats and functional activities such as getting up from and sitting down on high chairs.

The ROM should respect the angles of 0 to 45º, since shearing of the tibia occurs anteriorly, which spares the PCL from excessive tension, as well as protecting the femoropatellar joint[25]. Beyond 70 to 80º, the tensions increase considerably, thus causing excessive stress on the PCL[26].

When the hamstring muscles are contracted in isolation, i.e. in OKC exercises, the tension on the PCL is increased because of the traction force of these muscles on the tibia[2,26,34,35]. Shelburne and Pandy[26] demonstrated that the hamstrings are responsible for constant posterior tension and that as the knee flexion increases, the forces favoring anteriorization of the tibia diminish.

The protocols generally postpone the introduction of exercises directed towards the hamstrings with the aim of not excessively tensioning the graft during the initial postoperative phase. There is divergence between studies regarding when to start to work on the posterior muscles of the thigh, such that the suggested start is in the sixth[8], eighth[16], ninth[13], 16th[28] or 24th week[3,19,22]. In our protocol, hamstring exercises are postponed until the eighth week with the aim of sparing the posteriorization forces during the initial phase of the rehabilitation protocol.

Andersen et al[41] found that beyond 10 to 12 weeks after PCL surgery, for patients with functional ROM, normalized gait and little or no significant clinical complaint, there was less concern regarding the type of exercise, speed at which the exercise was performed and the muscles to be emphasized for normalizing these patients' muscle strength and restoring their remaining functional deficits.

Sensory-motor training

One of the structures that assist in proprioception for the knee is the PCL[42], because of the enormous quantity of mechanoreceptors found in this ligament. The proprioceptive effect of the PCL has mainly been studied and discussed in relation to preservation or not of this ligament in total knee prosthesis surgery. There have been divergent results regarding comparisons between knees with and without the ligament, in assessing functional outcomes for the knee[43].

Because of the PCL injury process and the role of the PCL in proprioception, sensory-motor training should always be performed. There should be progression from stable ground surfaces with static exercises to unstable surfaces with dynamic exercises that are increasingly specific to the functional objective[43].

FINAL REMARKS

The majority of the protocol proposed fits within the current evidence on this subject. The protocol has been used in our clinic with good tolerance among the patients. The present state of evidence has allowed us to analyze each phase of the rehabilitation process, but further studies of clinical nature with greater strength of evidence need to be conducted.

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Annex 1 – Rehabilitation protocol for posterior cruciate ligament.

REHABILITATION PROTOCOL

Date of surgery														
	Week								Month					
ACTIVITIES OF DAILY LIVING	1	2	3	4	5	6	7	8	3	4	5	6	7	8
PARTIAL LOADING	** ^	** ^	* ^	* ^	* ^									
FULL LOADING							# ^							
GOING UP AND DOWN STAIRS					# ^									
GOING UP AND DOWN STAIRS					# ^									
RUNNING										# ^		°		

* 1 CRUTCH; ** 2 CRUTCHES; *** WALKING FRAME
# RELEASE FOR WEIGHT-BEARING, ACCORDING TO PATIENT'S TOLERANCE
^ WITH EXTENSION BRACE
°REMOVAL OF BRACE

	Week								Month					
ROM (extension-flexion)	1	2	3	4	5	6	7	8	3	4	5	6	7	8
PASSIVE	*			0-70 *^		0-90 *^	↑ Progressive gain							
FREE ACTIVE						0-90	↑ Progressive gain							
PATELLAR MOBILIZATION														

NOTE: MINIMUM EXPECTED GAIN
* EMPHASIS ON EXTENSION (0°)
^ TIBIA STABILIZED POSTERIORLY

	Week								Month					
ANALGESIA	1	2	3	4	5	6	7	8	3	4	5	6	7	8
ELECTROANALGESIA (MINIMUM 30 MINUTES)														
CRYOTHERAPY (20 – 30 MINUTES)														
MOBILIZATION														

NOTE: CAN BE DONE EVERY TWO HOURS

	Week								Month					
KINESIOTHERAPY	1	2	3	4	5	6	7	8	3	4	5	6	7	8
STRETCHING (HAMSTRINGS AND TS)														
STRETCHING (QUADRICEPS)	# ^													
OKC (HIP FLEXION)														
OKC (HIP EXTENSION)														
OKC (HIP ADDUCTION)	# ^													
OKC (HIP ABDUCTION)														
OKC (KNEE FLEXION)								# ^						
OKC (KNEE EXTENSION)	#													
OKC (ANKLE)														
CKC (stable ground surface)		# ^												
CKC (unstable ground surface, without support)								# ^						
ERGOMETRIC BICYCLE						# ^								
EENM						Until muscle inhibition disappears								

RELEASE ACCORDING TO PATIENT'S TOLERANCE
^ WITH JOINTED BRACE

	Week								Month					
Sensory-motor	1	2	3	4	5	6	7	8	3	4	5	6	7	8
STABLE GROUND SURFACE (two feet)				#										
STABLE GROUND SURFACE (one foot)						#								
UNSTABLE GROUND SURFACE (two feet)						#								
UNSTABLE GROUND SURFACE (one foot)						#								
DISPLACEMENT (anteroposterior)								#						
DISPLACEMENT (side-to-side)									#					
DISPLACEMENT (pivot)										#				

RELEASE FOR WEIGHT-BEARING, ACCORDING TO PATIENT'S TOLERANCE

	Week								Month					
Plyometry	1	2	3	4	5	6	7	8	3	4	5	6	7	8
TWO FEET														
VERTICAL JUMP										#				
HORIZONTAL JUMP											#			
ONE FOOT														
VERTICAL JUMP											#			
HORIZONTAL JUMP												#		

RELEASE FOR WEIGHT-BEARING, ACCORDING TO PATIENT'S TOLERANCE

	Week								Month					
	1	2	3	4	5	6	7	8	3	4	5	6	7	8
RETURN TO SPORTS ACTIVITY												#		