Table 2 Nonoperative PCL rehabilitation protocol

Time following injury	Specific protocol
Phase I	Precautions
0–6 weeks after injury	PRICE (Protect, Rest, Ice, Compress, Elevate) protocol
	Avoid hyperextension (12 weeks)
	Prevent posterior tibial translation (12 weeks)
	Isolated hamstring exercises should be avoided until week 12
	Weight bearing
	Partial weight bearing with crutches (2 weeks)
	Range of motion (ROM)
	Prone passive ROM from 0° to 90° (Fig. 1) for the first 2 weeks, and then progress to full ROM
	Brace
	PCL Jack brace to be worn at all times, including rehabilitation and sleep (minimum of 12 weeks)
	Goals
	PCL ligament protection
	Oedema reduction to improve passive ROM and quadriceps activation
	Address gait mechanics
	Patient education
	Therapeutic exercise
	Patellar mobilizations
	Prone passive ROM (Fig. 1)
	Quadriceps activation
	Quadriceps sets
	Straight leg raises (SLR) once the quadriceps are able to lock joint in terminal extension and no lag is present
	Gastrocnemius stretching
	Hip abduction/adduction
	Stationary bike with zero resistance when ROM $> 115°$
	Weight shifts to prepare for crutch weaning
	Pool walking to assist with crutch weaning
	Calf raises and single leg balance when weaned from crutches
	Upper body and core strength as appropriate
Phase II 6–12 weeks after injury	Precautions
	Continued avoidance of hyperextension
	Prevent posterior tibial translation
	Limit double leg strengthening exercises to no more than 70° of knee flexion
	Weight bearing
	Weight bearing as tolerated (WBAT)
	Range of motion
	Full ROM, supine and prone ROM after 6 weeks
	Brace
	PCL Jack brace to be worn at all times
	Goals
	PCL ligament protection
	Full ROM
	Address gait mechanics during crutch weaning
	Double leg strength through ROM (no greater than 70° knee flexion) and single leg static strength exercises
	Reps and set structure to emphasize muscular endurance development (3 sets of 20 reps)
	Therapeutic exercise
	Continue PRICE protocol

Table 2 continued

Time following injury	Specific protocol
	Continue exercises as weeks 1–4
	Gastrocnemius and light hamstring stretching
	Leg press limited to 0–70° of knee flexion (Fig. 2)
	Squat progression (squat → squat with calf raise → squat with weight shift)
	Static lunge (Fig. 3)
	Hamstring bridges on ball with the knees extended (Fig. 4)
	Progressive resistance stationary bike
	Light kicking in pool
	Incline treadmill walking (7–12% incline)
	Single leg dead lift with the knee extended (Fig. 5)
	Proprioceptive and balance exercises
Phase III	Brace
13–18 weeks after injury	Discontinue PCL Jack brace
	Goals
	Reps and set structure to emphasize muscular strength development
	Progress ROM strength to beyond 70° knee flexion
	Isolated hamstring exercises may begin after week 12
	Prepare athlete for sport-specific activity
	Therapeutic exercise
	Double leg press with progression to single leg (Fig. 2)
	Single leg knee bends
	Balance squats (Fig. 6)
	Single leg dead lift (Fig. 5)
	Single leg bridges starting during week 16 (Fig. 7)
	Continue bike and treadmill walking
	Running
	Running is allowed once the patient has demonstrated sufficient strength and stability with functional exercise and quadriceps girth is greater than or equal to 90% compared to the contralateral normal side.
	Outline:
	Week 1: 4 min walk; 1 min jog for 15–20 min
	Week 2: 3 min walk; 2 min jog for 20 min
	Week 3: 2 min walk; 3 min jog for 20 min
	Week 4: 1 min walk; 4 min jog for 20 min
	Once running progression is completed, continue single plane agility with progression to multi-planar agility
	Clinical examination and/or PCL stress radiographs to objectively verify healing of PCL after week 15
Phase IV	Continue exercises and protocol from weeks 13–18
19 + weeks after injury	Set and reps structure to emphasize muscular power development (3 sets of 4–8 reps)
	Sport-specific agility exercises
	Non-contact return to play following clearance by the operating physician
	Full contact return to play when specific return to sports criterion met:
	Full active ROM
	Greater than 85–90 % normal quadriceps strength
	No evidence of instability or giving way
	Greater than 90 % function on return to sports testing
	Athlete is mentally ready to return to sport and not timid or fearful of re-injury

on the other hand, should not be attempted until sufficient time has passed to allow for healing of the injured ligament or reconstruction graft [9, 51].

In addition, further strain is placed on the PCL during active contraction of the hamstring muscles [49]. A proper rehabilitation programme should minimize these forces during PCL rehabilitation to allow for successful graft/ligament healing. This is readily accomplished by keeping the knee immobilized using an anterior directed drawer force and by not allowing active isolated hamstring exercises until an appropriate time during rehabilitation (12 weeks after starting a nonoperative rehabilitation programme and 24 weeks following surgery). Because graft healing in PCL reconstructions has been reported to take nearly twice as long compared to ACL reconstructions, it has been reported that keeping PCL reconstruction patients non-weight bearing for 6 weeks is necessary to allow for adequate graft healing and revascularization to occur [1, 4, 21].

Eccentric weakness of the quadriceps and hamstrings has been reported as major factors that need to be addressed following PCL injuries [31]. This suggests that eccentric strengthening, including open and closed kinetic chain exercises, should be a vital part of any therapy. Open and closed kinetic chain exercises are the foundation of PCL rehabilitation protocols; however, OKC exercises should only be used with limited flexion angles until the ligament/graft has had adequate time to heal [36].

Open kinetic chain exercises are able to isolate single muscle groups for strengthening, which makes them especially important in the early weeks following PCL injury or surgery [36]. However, OKC exercises that activate the hamstrings should be avoided in the initial phases of PCL rehabilitation, because studies have reported that they can stretch out grafts or cause further injury to the already damaged ligament [29, 30].

Closed kinetic chain exercises are unable to isolate a single muscle group because they activate antagonistic muscle groups across multiple joints [30]. They can also produce increased shear forces on the healing ligament. For these reasons, CKC exercises should be initially avoided while OKC exercises are used to strengthen the quadriceps during the early stages of rehabilitation [56].

Closed chain exercises, including squats and leg presses (Fig. 2), are ideal for strengthening the quadriceps and gluteal muscles [30]. It has been reported that the eccentric squat is an excellent exercise to increase quadriceps strength during any form of lower extremity rehabilitation [32]. Strengthening the quadriceps is especially important in PCL rehabilitation, because the quadriceps secondarily contribute to anteroposterior stability with the PCL, and, as previously stated, patients with improved quadriceps strength typically achieve significantly better outcomes following PCL injury [32]. Escamilla et al. [10] favoured leg presses with a narrow stance over squats during the initial phases of PCL rehabilitation. This is because squats generate greater PCL tensile forces than leg presses over varying knee flexion angles. Once the quadriceps strength of the injured side is great than or equal to 90 % compared to the uninjured side, the patient can begin a progression of running activities [53].

Reports have suggested that therapists and physicians should use caution when allowing patients to begin forward and side lunge exercises in the rehabilitation process, due to the high forces on the PCL that are generated by these exercises [11]. Lower knee flexion angles and a shorter stride lunge should be used when starting such exercises, because they have been reported to generate the least force on the PCL [12].

The limitations of this study are that it is a review article and does not have any outcome data to support the recommendations made. The studies which were reviewed all came from the English-based literature and reports published in other languages were not considered. This review clearly demonstrates that there is a paucity of peer-reviewed data comparing suggested forms of PCL rehabilitation and the impact they have on patient outcomes. Therefore, future research is needed to investigate and establish an accepted protocol for PCL rehabilitation. Based on these reports, the studies reviewed above, and the author's clinical experience, recommended postoperative and nonoperative programme for patients following PCL injury are presented in Tables 2 and 3, respectively.

Conclusions

An optimal set of guidelines for nonoperative or postoperative management of PCL injuries has not yet been defined or agreed upon. There is a lack of peer-reviewed publications comparing the subjective and objective outcomes of both postoperative PCL rehabilitation and nonoperative treatment programmes. Future studies need to define outcomes for various PCL rehabilitation programmes to allow practitioners to agree on and implement the most effective protocols to improve patient outcomes.

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