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Research Paper

Role of Physiotherapy in Preventing Failure of Primary Anterior Cruciate Ligament Reconstruction
首次前十字韌帶重建手術後物理治療所扮演的角色

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ABSTRACT

Background/Purpose: Anterior cruciate ligament (ACL) reconstruction is routinely performed in sports medicine. We aimed to determine if there is any protective effect of postoperative physiotherapy in preventing graft rupture after primary ACL reconstruction (ACLR).
Methods: A retrospective case–control study was carried out, with demographic data, concomitant meniscal injury, and intraoperative fixation methods matched. The number of sessions of physiotherapy attended by the rupture group and nonrupture group were compared using binary logistic regression.
Results: No significant relationship between the frequency of postoperative physiotherapy and occurrence of graft rupture after primary ACLR was identified.
Conclusion: Further research is needed to verify the effect of physiotherapy in the prevention of graft rupture after primary ACLR.

中 文 摘 要

前十字韌帶重建手術在運動醫學中十分普遍。我們希望找出首次接受前十字韌帶重建手術後物理治療能否保護該韌帶。我們針對首次接受前十字韌帶重建手術的病人做了病例對照研究，研究對象中我們已配對年齡、性別、有沒有同時的半月板受損以及已重建前十字韌帶的固定方法。我們透過二項對數迴歸模式比較了術後前十字韌帶有受損及沒有受損病人的參與物理治療次數。是次研究未有發現重建後的前十字韌帶受損與參與物理治療次數有關。

Introduction

Anterior cruciate ligament reconstruction (ACLR) is a very common operation in sports medicine. About 100,000 ACLRs are performed each year in the United States of America.[1] A failure rate of 4% can be estimated from the available randomised control trials for single bundle reconstruction [2–5]. The total ACL graft rupture rate was 6.2% (173 of 2782; range, 0–13.4%).[6] Bourke et al[7] reported a 2.45% annual rate of ACL graft rupture within 2 years after primary ACLR, but annual rates declined subsequently to 0.42% at up to 15 years after primary ACLR. Similarly, other studies have documented an annual rupture rate of 0.3–1.3%.[7]

The outcome in patients who received primary ACLR followed by physiotherapy was studied. It has been shown that physiotherapy can improve the primarily reconstructed knee in terms of muscle strength of flexor and extensor,[8] anterior knee laxity, and rotational instability.[9] Symptoms and functional status after physiotherapy in patients who received primary ACLR were studied by Feller et al[10] with multiple factors (age, gender, type of ACL graft, level of activity, and occupation before ACL injury) matched. Those who attended physiotherapy infrequently were found to have satisfactory (though not better) outcomes when compared with patients receiving regular physiotherapy. This finding seemed to contradict our belief that physiotherapy has a good clinical impact on the outcome of ACLR. We believe that further studies are needed to investigate the effect of physiotherapy on the outcome of ACLR.

Physiotherapy is hypothesised to have a protective effect in preventing rupture of ACL graft after primary ACLR through

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improved muscle strength,[8] anterior knee laxity, and rotational instability.[9] Our objective was to perform a retrospective study to investigate the association of physiotherapy with the occurrence of ACL graft rupture after primary ACLR.

Methods

A retrospective review of cases of primary ACLR was performed from 2000 to 2008 in Tuen Mun Hospital (TMH) and Pok Oi Hospital (POH), the New Territories West Cluster, Hospital Authority, Hong Kong. Most ACL reconstructions were performed in TMH. ACL reconstruction commenced in POH in December 2008 after the redistribution of manpower from TMH to POH. Preoperative physiotherapy was arranged for patients suffering from ACL rupture (see Table 1). ACLR was arranged when patients' knee injuries achieved adequate muscle strength and range of motion. Patients needed postoperative physiotherapy (see Table 2) to train up muscle strength, neuromuscular control, and agility.

The cases selected for our case–control study were patients with ruptured ACL graft occurring within 5 years after primary ACLR. The controls were patients without ruptured ACL graft after primary ACLR. Patients receiving physiotherapy in the New Territories West Cluster were included. In this study, cases and controls were matched regarding gender, age, concomitant meniscal injury with corresponding management (including intact meniscus, trivial tear not requiring meniscal surgery, or meniscal tear requiring partial menisectomy), and methods of tibial and femoral fixation of the ACL graft.

In this study, the number of sessions of physiotherapy attended by patients within 1 year after primary ACLR was recorded. Binary logistic regression was employed in the analysis of the relationship between the number of sessions of physiotherapy attended and rupture of the ACL graft after primary reconstruction. Potential confounding factors including age, gender, tibial fixation, femoral fixation, meniscal status, and time between initial ACL injury and primary ACLR were analysed in the logistic regression. Statistical significance was defined as $p < 0.05$. The statistical analysis was performed by SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA). This study protocol was approved by the New Territories West Cluster Clinical and Research Ethics Committee, Hospital Authority, Hong Kong. Cases with an identifiable technical cause of the ACLR failure (e.g. unsatisfactory tunnel position resulting in rotational instability) or concomitant ligamentous injury of the same knee were excluded from this study.

Results

There were 275 primary ACLRs using bone–patellar tendon–bone (BPTB) graft performed from 2000–2008. We identified 14 cases of graft rupture, of which 5 cases were excluded from this study. Regarding these 5 cases, the characteristics could not be matched in 1 case, undocumented collateral ligament and posterior cruciate ligament status was found in 1 case, vertical tunnel for ACL grafts was found in the remaining 3 cases (Figures 1A–C). Nine cases and 33 controls were employed in this study. The patient characteristics are illustrated in Table 3.

The number of sessions of physiotherapy attended in 1 year was plotted against the rupture and nonrupture group in a boxplot in Figure 2. The boxplot illustrated higher attendance of physiotherapy in the nonrupture group than the rupture group. The mean numbers of attendance in 1 year were 18.05 ± 12.85 in the rupture group and 18.58 ± 13.72 in the nonrupture group. However, there was no significance difference in the number of attendance between these two groups.

Table 4 illustrates the binary logistic regression coefficients and odd ratios for each of the predictors. Employing a 0.05 criterion of statistical significance, there was no significant difference in the numbers of sessions of physiotherapy attended by patients within 1 year after primary ACLR between the rupture and nonrupture group. No significant relationship was found between the outcome of primary ACLR and age, gender, tibial fixation, femoral fixation, meniscal status, and time between initial ACL injury and primary ACLR.

Table 1
Preoperative physiotherapy protocol*

Acute phase	Days 1–14	● Ice therapy
● Goal		● Flowpulse therapy
■ Decrease pain & swelling		● Weight bearing as tolerated with 2 crutches
■ Maintain ROM		● Quadriceps set exercises
■ Prevent muscle atrophy		● Co-contraction exercise of quadriceps & hamstrings muscle
		● Heel slide within pain tolerated
		● Straight leg raises exercise with 4 planes
		● Standing hamstring curls
	Weeks 2–4	● Begin PREs in knee extension
Intermediate phase (Weeks 4–7)	Weeks 4–6	● PRE knee extension progression to 20 lbs as tolerated
● Goal		● Stationary bike exercise
■ Aim at full ROM		● Lateral step up exercise
■ Increase muscle strength		● Minisquats exercise
■ Proprioceptive training		● Slide board for mobilisation
		● Calf raises
		● Eccentric hamstring work
		● Double leg press
		● Retro walking
		● May begin submaximal isokinetic work at 45–90° flexion at 180°/s
		● Proprioception & balance training
	Weeks 6–8	● Eccentric quadriceps exercise
		● Single leg press
		● Isokinetic exercise at 180°/s & 240°/s
		● Proprioception & close kinetic chain exercises
Advanced phase		● Functional testing at post-injury 12th week
		● Hop test
		● Isokinetic muscle testing
		● Agility drills
		● Isokinetic evaluation for H/Q ratio if needed

ROM = range of motion; PRE = progressive resistance exercises.
* Rationale: development of total leg strength; proprioception training; return to previous level of functional activity.

Table 2
Postoperative physiotherapy protocol

Week	ROM	Gait	Modalities	Therapeutic exercise/goal/wound care
1	Knee immobiliser in full extension	Weight bearing as tolerated with crutches (symmetric gait)	● Ice therapy	● Ankle mobilisation & calf stretching exercise in NWB position ● Hip abduction/extension exercise against gravity (with immobiliser) ● Assisted active knee flexion exercise as pain tolerated (off immobiliser) ● Passive knee extension exercise (off immobiliser) ● Static quadriceps exercise
2	Off knee brace Aim at 0–90° flexion	FWB ± crutches	● Ice therapy ● Magnetic field therapy ● Flowpulse therapy ● Electrical muscle stimulation for poor active muscle contraction	● Continue Week 1 exercise ● If knee extension loss is >20° ■ Knee extension splint ■ Passive extension with weight in front of knee ● Wound: primary wound care at Days 10–14
3	0–90° flexion	FWB & off crutches	● Continue swelling control if persisted swelling ● Continue electrical muscle stimulation for poor active muscle contraction	● Stationary bike with high seat (knee range, 0–90° flexion) ● Thera-band for quadriceps, hamstrings & glutei muscle CKC exercise (withhold the hamstrings CKC exercise for the semitendinosus graft reconstruction until postop Week 6) ● Straight leg raise exercise (no weight, 30 repetition × 3 set each day) ● Stair master with affected limb ● Inclined leg press
5–8	Start passive knee mobilisation if ROM <125°		● Wean off the swelling control modality if swelling subside	● Continue the Week 4 exercises ● Week 5: water aerobics (exercise pamphlet): flutter kicks only & no whip kick ● Week 6–8: power walk exercise (heel–toe gait) with treadmill for 10 min
8–12				● Continue the stair master, leg press & CKC exercises ● BAPS balance board ● Power walk exercise or jogging with treadmill with speed increased as tolerated for 10 min ● Mini-trampoline exercise ● Side to side lunges with profitter ● Single leg hop (vertical) exercise as tolerated ● Pool jogging or running ● Goal ■ ROM 0–125° ■ No knee swelling ■ Quadriceps & hamstrings muscle with Grade 4 in Oxford scale ■ Single leg static balance >30 s
12–20				● Continue Week 8 exercises ● Isokinetic strengthening exercise with concentric mode at 120, 180, & 240 angular speed ● Hop test: time hop & distance hop ● Shuttle run test ● Figure of 8 test ● Goal ■ Good knee stability in ADL ■ Quadriceps & hamstrings muscle with Grade 5 in Oxford scale ■ Good static & dynamic balance ■ Perform the agility tests
26				● Goal ■ Quadriceps & hamstrings muscle strength with 75–80% as compared to good side by isokinetic testing ■ Good static & dynamic balance ■ Resume sports specific practice if good stability ● Physiotherapy role ■ Check the home CKC exercises ■ Monitor the strength, balance, & agility progress

BAPS = Biomechanical Ankle Platform System; CKC = closed kinetic chain; FWB = full weight-bearing; NWB = non-weight-bearing; ROM = range of motion

Discussion

After ACLR, neuromuscular abnormality is well known as an important risk factor for ACL graft injury. Weakness of muscle, joint effusion, lack of normal range of motion, and impaired knee function can persist for months in the reconstructed knee after primary ACLR.[11] These significantly alter neuromuscular control of the reconstructed knee[11] and hence precipitate graft injury.[12] Quadriceps function recovery was also advocated to optimise the function of the reconstructed knee in athletes.[13–18] Athletes with a minimum of 20% deficit post-ACLR in the quadriceps strength walk with a gait pattern and truncated knee motion similar to acutely

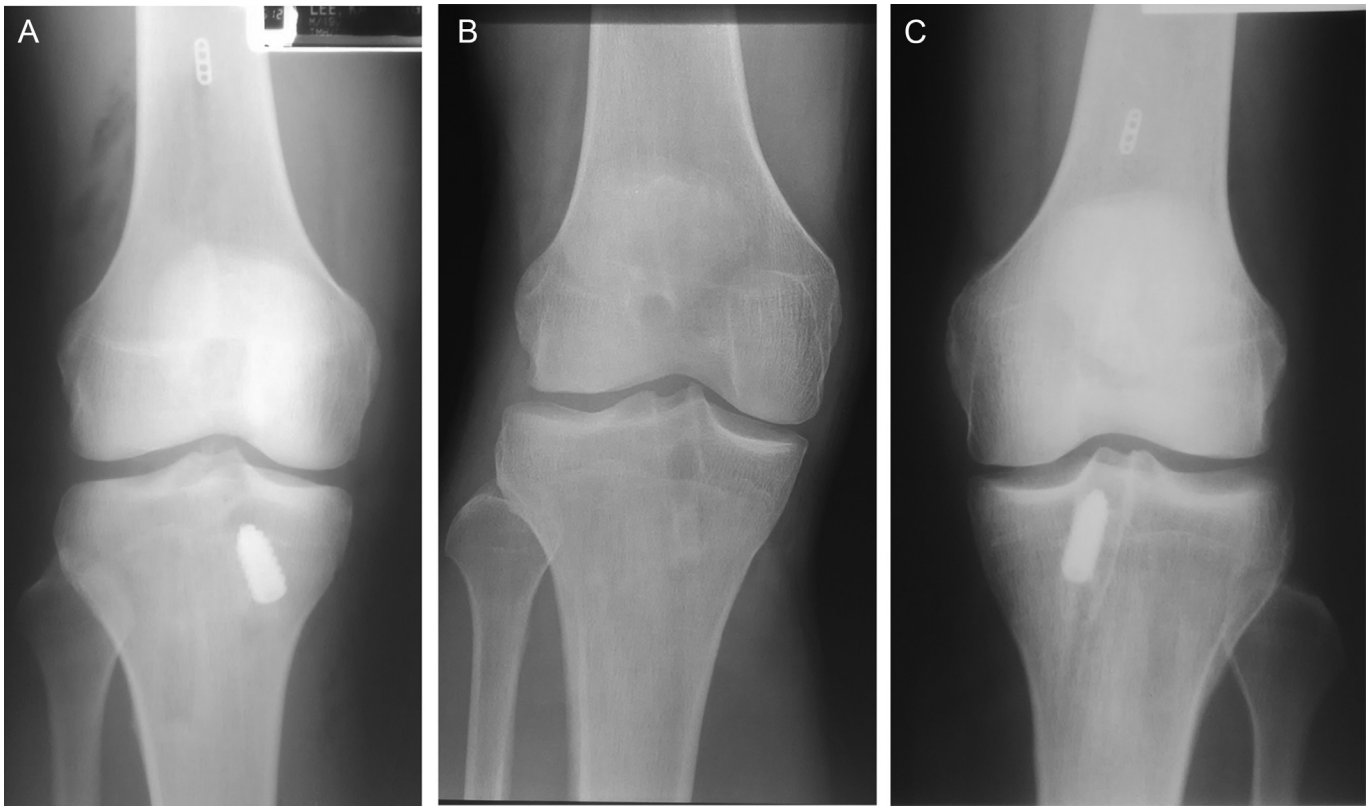

Figure 1. X-rays showing the three cases of vertical tunnel for ACL graft.

Table 3
Patient characteristics

		Case	Control
Gender	Male	8	31
	Female	1	2
Age (y/o)		22.78 ± 3.60	21.42 ± 4.36
Time between injury and operation (mo)		21.06 ± 2.01	21.00 ± 2.48
Lateral meniscus	Intact	6	28
	Trivial tear	1	0
	Yes, partial menisectomy	2	5
Medial meniscus	Intact	8	32
	Trivial tear	1	1
Femoral fixation	Endobutton	4	22
	Bioabsorbable screw	2	2
	Endobutton + bioabsorbable screw	2	6
	Metallic interference screw	1	3
Tibial fixation	Metallic interference screw	5	25
	Bioabsorbable screw	4	8

injured athletes.[17] Neuromuscular response can persist in bilateral lower limbs after ACL injury and may be exacerbated after ACLR.[16–18] Kinematics and kinetics of bilateral knee were found to change within 3 months after ACLR in a group of active athletes.[19] Peak angle, moment, and power of the knee joint were higher in the uninvolved limb of athletes after ACLR when compared with controls, which were similar in patients with acute ACL deficiency.[20–24] Four predictive factors of secondary ACL injury were indicated by regression analyses performed by Paterno et al[12]: net moment impulse of rotation of the uninvolved hip during landing, frontal-plane knee motion at the time of landing, asymmetries of sagittal-plane knee moment during initial contact, and postural stability deficits over the reconstructed lower limb. These modifiable predictors of graft injury risk emphasise the importance and need of targeted return-to-sport rehabilitation.

The relationship between compliance with physiotherapy and occurrence of graft rupture after primary ACLR was not established in the literature according to our knowledge. Physiotherapy after ACLR was arranged to strengthen the surrounding muscle after the reconstruction.[8] We postulated that there was better compliance with physiotherapy in the nonrupture group when compared with the rupture group, which was believed to be reflected through higher physiotherapy attendance. If the postoperative knee is well-trained in terms of muscle strength and neuromuscular control, it is expected to be more stable. The improved muscle strength and neuromuscular control were postulated to protect the primarily reconstructed ACL from rupture. Hence a well-trained knee is less predisposed to knee sprain and subsequently knee injury. However, the protective effect of physiotherapy against rupture of the ACL graft failed to be identified in this study.

Risk factors for repeated ACL injury included a return to competitive side-stepping, pivoting, or jumping sports, and the contact mechanism of the index injury.[25] After primary ACLR, five patients were documented as suffering from knee injury during sports including soccer, basketball, and running. Three patients had a history of knee sprain. One patient did not have any documented history of injury.

The other possible factor for repeated ACL injury is incomplete ligamentisation of the ACL graft. Ligamentisation is the remodelling of ACL graft tissue from tendinous to ligamentous form specific to native ACL histologically and biochemically. This usually completes within 2 years.[26] Histological and biochemical analyses have demonstrated that the ACL graft does not have adequate mechanical strength for at least 1 year after ACLR,[27] where ligamentisation is in progress. Beynnon et al[28] found

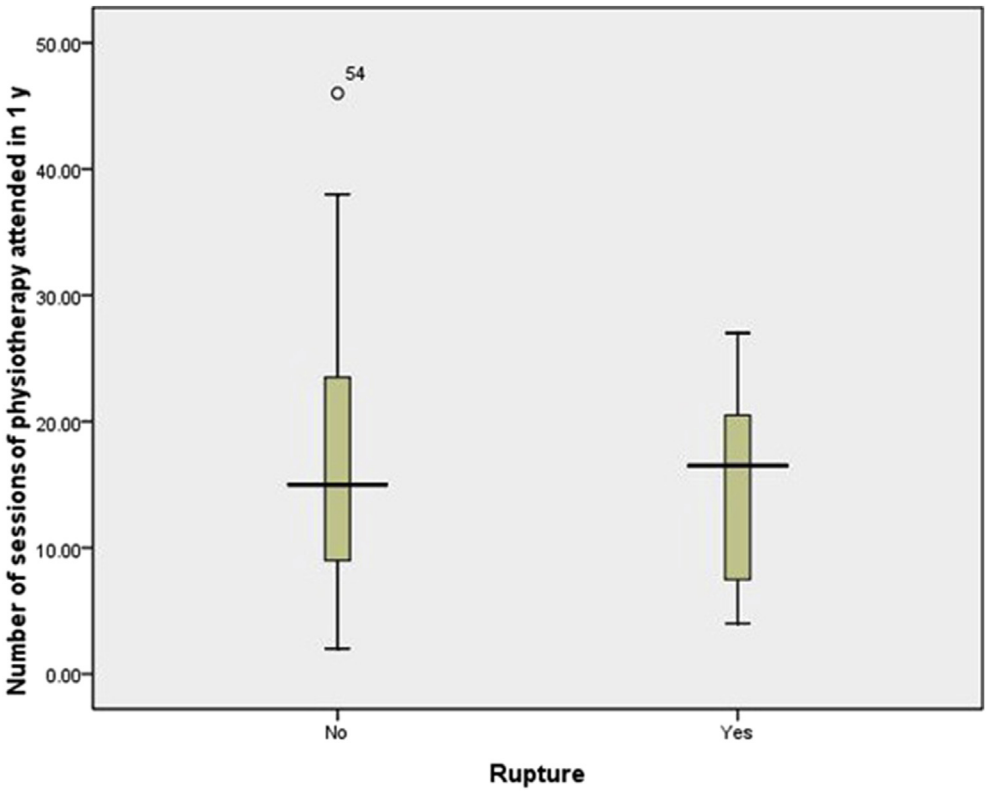

Figure 2. Boxplot illustrating higher attendance of physiotherapy in the nonrupture group than the rupture group.

Table 4
Results of binary logistic regression

		Physiotherapy in 1 year		
		B	Odds radio	*p*
Number of sessions of physiotherapy		0.005	1.005	0.917
Time between initial injury & primary ACLR		−0.029	0.971	0.314
Gender	Female vs. male	−1.478	0.228	0.540
Age		0.210	1.233	0.197
Lateral meniscus	Intact			0.679
	Trivial tear vs. intact	−1.472	0.230	0.379
	Yes, partial menisectomy vs. intact	41.114	7.174×10^{17}	0.999
Medial meniscus	Trivial tear vs. intact	−2.114	0.121	0.543
Femoral fixation	Endobutton			0.573
	Bioabsorbable screw vs. endobutton	18.863	1.557×10^{8}	0.999
	Endobutton + bioabsorbable screw vs. endobutton	21.097	1.454×10^{9}	0.999
	Metallic interference screw vs. endobutton	20.315	6.648×10^{8}	0.999
Tibial fixation	Bioabsorbable screw vs. metallic interference screw	1.607	4.985	0.540

ACLR = anterior cruciate ligament reconstruction; B = logistic regression coefficient.

that increased force on the ACL graft was associated with increased graft laxity. Pinczewski et al[29] revealed that rupture of the ACL graft was significantly associated with instrumented laxity 2 years after primary ACLR. The early high rates of ACL graft rupture may be associated with the ligamentisation process of the ACL graft.[30] The mean duration of secondary ACL injury in our cases was 40.67 ± 13.37 months, with only one case having secondary ACL injury within 2 years after primary ACLR. One rupture case was documented to have incomplete ligamentisation, with the second ACL injury occurring 53 months after primary ACLR. The ligamentisation status was not mentioned in other cases. Although the information was inconclusive due to inadequate documentation on the ligamentisation status in the rupture cases, the mean duration of secondary ACL injury may give us an impression that incomplete ligamentisation played a less significant role in secondary ACL injury in our rupture cases. This is because the mean duration of secondary ACL injury in our case series was more than 2 years, the usual time of completion of ligamentisation of the graft.[23]

We suspected that in cases of longer duration between ACL injury and reconstruction, the knee would be unstable for a longer period of time. As a result, the prolonged strain on the remaining ligaments of the injured knee may become lax. This may predispose the injured knee to have a higher chance of instability due to laxity of other ligaments in the reconstructed knee after ACLR, which may lead to secondary ACL injury. However, in this study, the relationship between the duration and graft rupture after primary ACLR failed to be demonstrated.

We have reviewed whether different femoral fixation methods were associated with ACL graft rupture. A total of 182 cases used Endobutton (Acufex Microsurgical Inc., Mansfield, MN, USA) only (4 cases of rupture, 2.2%). In 24 cases a bioabsorbable interference screw together with Endobutton (Acufex Microsurgical Inc.) as double femoral fixation was used (2 cases of ACL graft rupture, 8.3%). In 21 cases a bioabsorbable interference screw alone was used (2 cases of rupture, 9.5%). Finally, 23 cases used a metallic interference screw and Endobutton (Acufex Microsurgical Inc.; 1 case of rupture, 4.3%). In fact, the ACL graft rupture rate for patients using Endobutton (Acufex Microsurgical Inc.) as femoral fixation was lower, as compared to other methods of femoral fixation. The binary logistic progression showed that there was no significant relationship found between the outcome of primary ACLR and femoral fixation. This finding was consistent with the finding by Kousa et al,[18] in which there was no significant difference in the yield load of the single cycle loading test of the ACL graft after loading for 1500 cycles among EndoButton CL (Acufex Microsurgical Inc.), BioScrew (Linvatec Inc., Largo, FL, USA), a bioabsorbable interference screw, and SmartScrew ACL (Bionx Implants Inc., BlueBell, PA, USA).

In our study, although the sample size is expected to be small, we need to recognise the fact that ACL graft rupture after primary ACLR is uncommon. Several limitations were identified in our study. First of all, some records were incomplete or irretrievable. In three cases of graft rupture X-ray films were irretrievable, resulting in difficulty in identifying the potential technical cause of rupture in the primary ACLR. Some of the nonrupture cases could not be recruited as controls due to inadequate documentation regarding concomitant ligamentous or meniscal injury. In this study, the medical records traced were either in electronic or written form. In Hong Kong, most patients are treated in the Hospital Authority, a public organisation funded by the Hong Kong Government.[31,32] Their medical records were electronically documented in the clinical management system. Hence, the possibility of missing a case of secondary ACL injury was low but still possible. Secondly, numbers of sessions of physiotherapy attended between the rupture and nonrupture group were compared in this study. This parameter was objective, well documented in the clinical management system, and easily retrieved in this retrospective study. Other physiotherapy records, which were in written form, were already irretrievable in the period we researched (from 2000 to 2008). However, the number of sessions of physiotherapy attended may not reflect the duration of each session and quality of physiotherapy received by the patient, which was believed to affect the outcome of primary ACLR. Some patients may receive physiotherapy in the private sector, although we believe the number of these patients was small. Some patients may require longer, more intensive physiotherapy, but this is unknown due to irretrievable documentation. Further study is needed to demonstrate the relationship between physiotherapy and the occurrence of graft rupture after primary ACLR with standardised duration of session and quality of physiotherapy. In fact, postoperative physiotherapy is composed of many elements. Studies on which components of physiotherapy are correlated with a good functional outcome or the prevention of ACL graft rupture after primary ACLR are needed. Thirdly, some potential confounding factors were not included in this study, such as motivational level and rate of progress of physiotherapy.

Other potential confounding factors including age, gender, and methods of femoral and tibial fixation of the ACL graft were analysed in this study. However, no potential confounding factor was found. Further research is needed in order to determine the influence of the potential risk factors of graft rupture for patients who receive primary ACLR.

In this study, cases of primary ACLR performed with BPTB graft were included. In our department, BPTB grafts were used commonly before 2008 and hamstring grafts were commonly used from 2008 onwards. ACL graft rerupture after primary ACLR is an uncommon complication. Therefore, an adequate number of cases with adequate follow-up times are required to recruit a statistically significant number of suitable cases and controls. We hope to collect adequate ACLR cases using hamstring graft for study in the future, as the number of graft rupture cases is too small to yield significant findings at this moment.

Conclusion

No significant relationship was identified between the frequency of physiotherapy and the occurrence of graft rupture after primary ACLR according to our study. No other factor was found to correlate with graft rupture after primary ACLR. Further research is needed to verify the effect of physiotherapy in the prevention of graft rupture after primary ACLR.

Conflicts of interest

The authors have no conflicts of interest to declare.

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