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Original article

Quantifying anterior knee pain during specific activities after using the bone-patellar tendon-bone graft for arthroscopic anterior cruciate ligament reconstruction

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ABSTRACT

Background/objective: There has been much debate about the optimal graft choice for an anterior cruciate ligament (ACL) reconstruction. Anterior knee pain is a common donor site problem when using a bone-patellar tendon-bone (BPTB) graft. However, knowledge of the characteristics of anterior knee pain during different daily activities is still limited. This study aimed to determine the incidence of anterior knee pain and to quantify the degree of pain during a range of daily living activities.

Methods: Thirty-five patients who were scheduled to undergo an ACL reconstruction with an autologous BPTB graft between February 2015 and December 2016 were enrolled. A visual analogue scale (VAS) for pain was recorded during each of the following activities: ascending at 30-degree slope, ascending and descending stairs, running, jumping, squatting, kneeling, sitting cross-legged, and sitting one-legged. Demographic data, the range of motion, the area of decreased sensation, and the IKDC score were collected and compared 3 and 6 months postoperatively.

Results: The 35 male patients had a mean age of 29.7 years. Postoperatively, the mean IKDC scores were 58.1 ± 9.8 at 3 months and 72.7 ± 10.5 at 6 months. The incidences of overall anterior knee pain were 62.9% and 34.3% at the 3- and 6-month time points. Kneeling was the only activity that produced severe pain. At 3 months postoperatively, kneeling's mean VAS pain score was 3.9 ± 2.9 (2.9, 4.9; 95% CI for mean for 17 patients [48.5%] with considerable pain), whereas at 6 months postoperatively, it was 2 ± 2.5 (1.2–2.9; 95% CI for mean for 9 patients [25.7%] with considerable pain). The area of numbness of the proximal leg decreased from $12.8 \pm 18.3 \text{ cm}^2$ (6.4, 19.2; 95% CI for mean) to $3.2 \pm 9.1 \text{ cm}^2$ (0.1, 6.5; 95% CI for mean) at 3 and 6 months postoperatively.

Conclusions: Kneeling was the most challenging activity in terms of creating considerable levels of anterior knee pain in patients who had undergone an ACL reconstruction using a BPTB graft. Other knee activities, however, did not create moderate or severe degrees of anterior knee pain. Both anterior knee pain and numbness at the proximal leg improved over time.

Trial registration number: TCTR2018–0630002.

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Introduction

Anterior cruciate ligament (ACL) injuries are one of the most common knee ligament injuries.¹ Arthroscopic ACL reconstruction is a standard treatment for patients who have functional knee

instability. The two most commonly used autografts are the bone-patellar tendon-bone (BPTB) graft and the hamstring tendon autograft. However, recent literature reviews indicate that the choice of the optimal autograft remains controversial.^{2,3}

A BPTB graft is the preferred choice of graft fixation, especially for young athletes who are involved in contact sports.⁴ Bone blocks at both ends of the BPTB graft provide strong fixation strength with bone-to-bone healing, which permits athletes to resume sporting activities faster than with a soft tissue graft.^{4,5} Although the BPTB graft provides superior stability, some studies have found that it has

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Fig. 1. Sitting cross-legged. Frontal (A) and lateral (B) views of a patient sitting with his knees wide apart and one foot on top of the other. The affected knee (indicated by the white arrowhead) is on the patient's right.

more donor-site morbidity such as anterior knee pain or kneeling pain.⁶

Many factors increase the risk of postoperative anterior knee pain.^{7,8} However, there have been limited studies to determine and quantify the degree and characteristics of anterior knee pain, which would be useful information for patients when selecting a graft. This study aimed to find the incidence of anterior knee pain experienced by patients who had undergone an ACL reconstruction using a BPTB graft. A secondary objective was to describe the severity of the pain during a range of daily activities, but particularly during kneeling, sitting cross-legged, and sitting one-legged, all of which are important knee positions in Asian cultures. It was hypothesized that kneeling would produce the most anterior knee pain, and that the level of anterior knee pain experienced during the test activities would decrease over time.

Materials and methods

Study design

This prospective study was approved by our hospital's Institutional Review Board. Prior to its commencement, all participants read an information sheet and signed an informed-consent form that had been approved by the Human Research Protection Unit of the hospital.

Patients who declined to participate or who experienced any discomfort during the study were able to withdraw. It was approved for registration at the Thai Clinical Trials Registry (<http://www.clinicaltrials.in.th>; registration number TCTR20180630002). The inclusion criteria were patients aged 18–45 years who were scheduled to undergo a primary, anatomical, single-bundle, ACL

reconstruction with a BPTB graft, using interference screw fixation, between February 2015 and December 2016. The exclusion criteria were patients who had preoperative anterior knee pain, any other knee ligament injury combined with the ACL (ipsilateral), extension deficit, or the presence of a patellofemoral chondral lesion. Patients who had undergone any meniscus repair or cartilage procedure (such as micro-fracture) were also excluded owing to the delayed progression in the early phase of postoperative rehabilitation.

Surgical technique and postoperative rehabilitation program

An anteromedial incision was made to harvest the BPTB graft. The paratenon was dissected and exposed medially and laterally to reveal the whole width of the patellar tendon. The central one-third of the patellar tendon was harvested, including approximately 2–2.5 cm of the bone plugs at both the patella and the tibial tubercle. The tendon was subsequently repaired at the posterior-half with interrupted sutures, and the paratenon was closed with absorbable sutures.

As to the anatomical, single-bundle, ACL reconstruction, the femoral tunnel was drilled at the center of the femoral footprint of the ACL using the transportal technique. The tibial tunnel was also drilled at the center of the tibial ACL footprint. The BPTB graft was fixed with a bioabsorbable interference screw, firstly to the femoral tunnel, and then to the tibial tunnel, at a position of full knee extension. The donor site's bone-defects at the patella and the tibial tubercle were filled with the autologous bone graft collected while trimming the bone plugs and drilling the tibial tunnel. A post-operative accelerated rehabilitation program was undertaken, starting with an early range of motion exercises and partial weight bearing, as tolerated, with the use of crutches.⁹



Fig. 2. Sitting one-legged. Frontal (A) and lateral (B) views of a patient sitting on the floor, with the affected knee (marked by the white arrowhead) below the contralateral knee.



Fig. 3. Kneeling. Frontal (A) and lateral (B) views of a patient sitting on both knees, with the torso in an upright position. The affected knee (denoted by the white arrowhead) is on the patient's right.

Data collection and statistical analysis

The demographic data collected comprised the patients' age, sex, body weight, and height. The length of the surgical scar was also documented; in addition, the range of knee motions, the Thai version of the International Knee Documentation Committee (IKDC) Subjective Knee Form,¹⁰ and the area of numbness were ascertained and/or collected at the 3- and 6-month postoperative follow-ups. At the two follow-up points, patients were asked to do the following activities: 1) walk on a treadmill with a slope of 30° at a speed of 2 km/h for 2 min; 2) run at a speed of 3 km/h for 2 min; 3) do stair-climbing of 20 steps up and then 20 steps down; 4) sit cross-legged (Fig. 1) for 2 min; 5) sit one-legged (surgical-side flat on the floor; Fig. 2) for 2 min; 6) jump 10 times on two legs; 7) squat 10 times; and 8) kneel on both knees (Fig. 3) for 1 min. The patients had a 1-min break after each activity to prevent the overlapping of pain from the previous activity. Following each activity, the patient's subjective assessment of the anterior knee pain in both knees was recorded using a 10-point visual analogue scale (VAS) for pain. The scale used the following cutoff points: mild pain, 0–3 points; moderate pain, 4–7 points; and severe pain, 8–10 points.¹¹ For the purposes of this study, “considerable” anterior knee pain was defined as “moderate-to-severe pain”, i.e., pain with a VAS score ≥ 4 .

The area of numbness was recorded by one surgeon. The patients were asked to delineate the area of decreased sensation around the surgical site. The longest line was drawn first, and then another line, perpendicular to the first, was drawn; the size of the numbness area (the length of the first line multiplied by the length of the second line) was then calculated (Fig. 4).

Descriptive statistics were used to summarize the demographic data. All categorical data were reported as a number or percentage, while the continuous data were reported either as the mean $\pm$ standard deviation and 95% confidence interval (CI), or as the median with a range, as appropriate. The Shapiro–Wilks test and visual inspection revealed if the data were sufficiently normal for the use of parametric statistics. McNemar's test was used on paired nominal data. In the case of continuous data, the paired *t*-test or the Wilcoxon's signed test was used, as appropriate, to find



Fig. 4. The area of decreased sensation was delineated by drawing the points of numbness near the surgical scar (marked by the black arrowhead). The longest line (L) was drawn first, followed by a line (W) perpendicular to it. The size of the numbness area was determined with the formula $L \text{ (cm)} \times W \text{ (cm)} = \text{area (cm}^2\text{)}$.

Table 1
Demographic data.

Variables	Mean $\pm$ SD or Number with percentages
Age (year)	29.7 $\pm$ 7.4
Weight (kg)	71.4 $\pm$ 11.7
Height (cm)	172.3 $\pm$ 5
Body mass index (kg/m ²)	24.0 $\pm$ 3.2
Mechanism of injury (number, %)	
Contact Sport	22 (62.9%)
Noncontact Sport	12 (34.3%)
Non-sport mechanisms	1 (2.8%)
Side (number, %)	
Right	22 (62.9%)
Left	13 (37.1%)
Range of knee motion (degree)	
Flexion	138.6 $\pm$ 7.1
Extension	0.3 $\pm$ 1.4
Length of the surgical scar (cm)	5 $\pm$ 0.6

differences. The statistical analyses were performed using SPSS for Windows, version 18 (SPSS Inc., Chicago, IL, USA). A *p*-value of <0.05 was considered the threshold for statistical significance.

Results

There were 38 eligible patients. Of those, 3 were excluded: 2 were lost to follow-up, and the third had a knee injury at home during the first 3-month postoperative period. The remaining 35 patients were all male, with a mean age of 29.7 years. Other demographic data were listed in Table 1.

The mean IKDC scores improved from 58.1 $\pm$ 9.8 to 72.7 $\pm$ 10.5 at the 3-month and 6-month postoperative time points. The mean IKDC difference was 14.6 $\pm$ 8.5 (11.6, 17.5; 95% CI of the difference) with *p*-value < 0.01. The mean area of the decreased sensation of the proximal leg was 12.8 $\pm$ 18.3 cm² (6.4, 19.2; 95% CI for mean) at the 3-month follow-up, but only 3.3 $\pm$ 9.1 cm² (0.1, 6.5; 95% CI for mean) at the 6-month time point with *p*-value < 0.01. The incidences of considerable anterior knee pain (i.e., pain with a VAS score $\geq$ 4 for any testing activity) were 62.9% at the 3-month and decreased to 34.3% at the 6-month postoperative time points (*p*-value = 0.02).

The mean VAS pain score for each activity are at Table 2. Of all the activities at the 3-month follow-up, kneeling produced the most severe pain, with a mean VAS pain score of 3.9 $\pm$ 2.9 (2.9, 4.9; 95% CI for mean), and it was the most frequent cause of considerable anterior knee pain (17/35 patients, or 48.5%). Moreover, there were two patients that could not perform kneeling due to discomfort at 3-month follow-up and one patient at 6-month mark. In contrast, no patients reported considerable pain while running or sitting cross-legged at the 3-month time point. At the 6-month

Table 3
Degree of anterior knee pain, by knee activity.

Activity	3-month follow up n (%)	6-month follow up n (%)	p-value
Ascending 30° slope			
- no pain	17 (48.6%)	29 (82.9%)	
- mild	17 (48.6%)	6 (17.1%)	
- moderate	1 (2.9%)	0 (0%)	
- severe pain	0 (0%)	0 (0%)	0.990
Running			
- no pain	16 (45.7%)	25 (71.4%)	
- mild	19 (54.3%)	10 (28.6%)	
- moderate	0 (0%)	0 (0%)	
- severe pain	0 (0%)	0 (0%)	0.999
Ascending stairs			
- no pain	12 (34.3%)	19 (54.3%)	
- mild	19 (54.3%)	15 (42.9%)	
- moderate	4 (11.4%)	1 (2.9%)	
- severe pain	0 (0%)	0 (0%)	0.375
Descending stairs			
- no pain	11 (31.4%)	23 (65.7%)	
- mild	19 (54.3%)	11 (31.4%)	
- moderate	5 (14.3%)	1 (2.9%)	
- severe pain	0 (0%)	0 (0%)	0.219
Sitting cross-legged			
- no pain	26 (74.3%)	34 (97.1%)	
- mild	9 (25.7%)	1 (2.9%)	
- moderate	0 (0%)	0 (0%)	
- severe pain	0 (0%)	0 (0%)	0.999
Sitting one-legged			
- no pain	28 (80.0%)	32 (91.4%)	
- mild	6 (17.1%)	2 (5.7%)	
- moderate	1 (2.9%)	1 (2.9%)	
- severe pain	0 (0%)	0 (0%)	0.999
Jumping			
- no pain	4 (11.4%)	14 (40.0%)	
- mild	23 (65.7%)	19 (54.3%)	
- moderate	8 (22.9%)	2 (5.7%)	
- severe pain	0 (0%)	0 (0%)	0.070 ^a
Squatting			
- no pain	16 (45.7%)	22 (62.9%)	
- mild	13 (37.1%)	13 (37.1%)	
- moderate	6 (17.1%)	0 (0%)	
- severe pain	0 (0%)	0 (0%)	0.031 ^a
Kneeling			
- no pain	3 (9.1%)	10 (29.4%)	
- mild	13 (39.4%)	15 (44.1%)	
- moderate	12 (36.4%)	7 (20.6%)	
- severe pain	5 (15.2%)	2 (5.9%)	0.039 ^a

Degree of anterior knee pain determined by VAS for pain: VAS = 0, no pain; VAS = 1–3, mild pain; VAS = 4–7, moderate pain; and VAS = 8–10, severe pain.

^a Difference of the considerable knee pain as a VAS pain score $\geq$ 4 of each activity with level of significant (*p*-value less than 0.05).

follow-up, kneeling continued to produce the most severe pain (with a mean VAS pain score of 2 $\pm$ 2.5 [1.2–2.9; 95% CI for mean]) as well as caused anterior knee pain the most often among the activities (9 patients, or 25.7%).

Table 2
Mean VAS pain score by activity, measured at 3 and 6 months postoperatively.

Activity	3-month follow up (n = 35)		6-month follow up (n = 35)		Difference (95% CI for difference)	p-value
	Mean $\pm$ SD (95% CI for mean)	VAS ^a $\geq$ 4 n (%)	Mean $\pm$ SD (95% CI for mean)	VAS ^a $\geq$ 4 n (%)		
Ascending 30° slope	0.9 $\pm$ 1.2 (0.5, 1.3)	1 (2.8%)	0.2 $\pm$ 0.6 (0.04, 0.4)	0 (0%)	0.7 $\pm$ 1.1 (0.3, 1.0)	<0.001 ^b
Running	1.1 $\pm$ 1.2 (0.7, 1.5)	0 (0%)	0.4 $\pm$ 0.7 (0.2, 0.6)	0 (0%)	0.7 $\pm$ 0.9 (0.4, 1.0)	<0.001 ^b
Ascending stairs	1.5 $\pm$ 1.5 (1.0, 2.1)	4 (11.4%)	0.7 $\pm$ 1.0 (0.3, 1.01)	1 (2.8%)	0.9 $\pm$ 1.7 (0.3, 1.5)	0.01 ^b
Descending stairs	1.7 $\pm$ 1.6 (1.1, 2.2)	5 (14.2%)	0.5 $\pm$ 1.00 (0.2, 0.9)	1 (2.8%)	1.1 $\pm$ 1.8 (0.5, 1.8)	0.01 ^b
Sitting cross-legged	0.4 $\pm$ 0.9 (0.1, 0.7)	0 (0%)	0.1 $\pm$ 0.3 (0.1, 0.2)	0 (0%)	0.4 $\pm$ 0.8 (0.1, 0.6)	0.01 ^b
Sitting one-legged	0.5 $\pm$ 1.2 (0.1, 0.9)	1 (2.8%)	0.2 $\pm$ 0.9 (0.1, 0.5)	1 (2.8%)	0.2 $\pm$ 0.8 (−0.04, 0.5)	0.10
Jumping	2.2 $\pm$ 1.6 (1.7, 2.8)	8 (22.8%)	1.0 $\pm$ 1.1 (0.6, 1.4)	2 (5.6%)	1.2 $\pm$ 1.6 (0.7, 1.8)	<0.001 ^b
Squatting	1.5 $\pm$ 2.0 (0.9, 2.2)	5 (14.2%)	0.4 $\pm$ 0.7 (0.2, 0.7)	0 (0%)	1.1 $\pm$ 1.9 (1.8, 3.4)	0.01 ^b
Kneeling	3.9 $\pm$ 2.9 (2.8, 4.9)	17 (48.5%)	2.0 $\pm$ 2.5 (1.2, 2.9)	9 (25.7%)	1.9 $\pm$ 3.6 (0.6, 3.1)	0.01 ^b

^a VAS, visual analogue scale for pain. Considerable anterior knee pain was defined as a VAS pain score $\geq$ 4.

^b Statistically significant level, with a value < 0.05.

The VAS pain scores for the knee activities were also subdivided into no pain, mild, moderate, and severe pain categories (Table 3 and Fig. 5). Most of the considerable anterior knee pain (i.e., pain with a VAS score ≥ 4 points) fell in the moderate-knee-pain range (i.e., a VAS pain score of 4–7 points). Depending on the knee activity, the proportion of patients experiencing moderate pain was in the range of 2.9%–36.4% at the 3-month follow-up, and 2.9%–20.6% at the 6-month follow-up (Table 3). By contrast, severe anterior knee pain (a VAS pain score of 8–10 points) was only found with kneeling, with 15.2% of patients reporting it at the 3-month time point and 5.9% at the 6-month mark.

Discussion

In this study, 62.9% of patients at the 3-month follow-up experienced moderate-to-severe anterior knee pain during at least one activity after ACL reconstruction with a BPTB autograft, but the incidence was substantially lower (34.3%) at 6 months

postoperatively. Moving on to the incidence of considerable pain by knee activity, kneeling had the highest incidence at both the 3-month mark (48.5%) and the 6-month time point (25.7%). As to the activities other than kneeling, they mostly involved no pain or mild pain, and at the 6-month mark, the incidence of moderate pain did not exceed 10% for any of those activities; moreover, none of them involved severe pain at either the 3- or 6-month timepoints.

The incidence of anterior knee pain in this study (34.3%–62.9%) was in a similar range to the results of other studies, which reported 33%–48%.^{12,13} Unlike the present study, however, the incidence of anterior knee pain reported by those other studies increased as the follow-up time period increased. Pinczewski et al.¹² found that 33% of patients had kneeling pain at the 2-year follow-up, but the figure increased to 59% at the 10-year follow up. In the present study, the percentage of patients with anterior knee pain reduced significantly between the 3-month and 6-month follow-up points. This may be related to the surgical techniques that we employed to

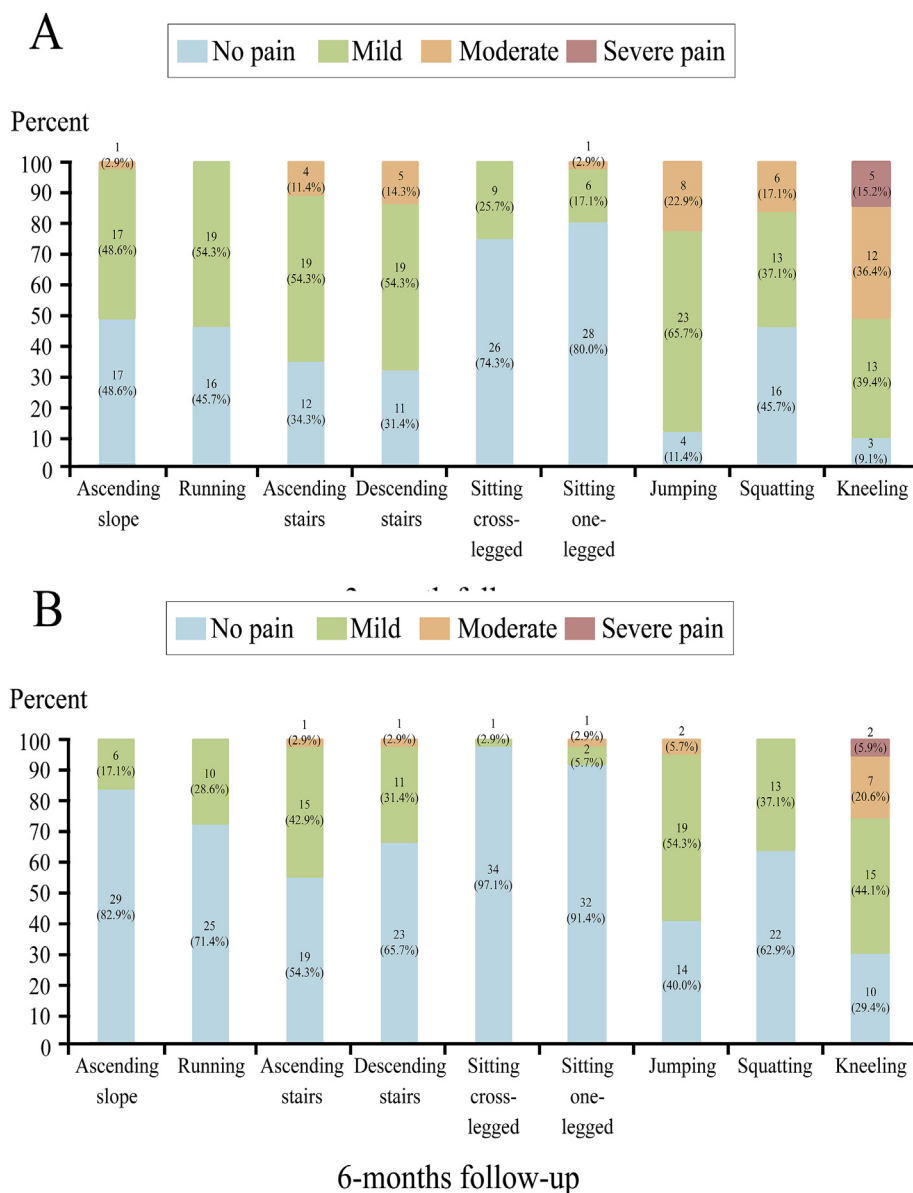


Fig. 5. Severity of VAS pain scores for different knee activities. (A) Severity of VAS pain at 3 months and (B) 6 months postoperatively. VAS = 0, no pain; VAS = 1–3, mild pain; VAS = 4–7, moderate pain; and VAS = 8–10, severe pain.

reduce anterior knee pain, namely, repairing the paratenon and filling the donor-site bone defects at the patella and tibial tubercle with autologous bone graft. However, it is assumed that the incidence of anterior knee pain experienced during knee activities in the current study may have risen if the follow-up period had been longer than six months.

Many factors can increase the risk of postoperative anterior knee pain after ACL reconstruction using a BPTB graft.^{7,8} Niki et al.⁸ found that a knee extension deficit is the main factor for postoperative anterior knee pain during the early postoperative period. However, the current study excluded patients with an extension deficit that may have resulted in anterior knee pain. Moving on to the graft harvesting technique, injury to the infrapatellar branch of the saphenous nerve and histologic changes to the donor site's healing process (tendinopathy) are the main reason for anterior knee pain.⁷ Several methods are employed to minimize the risk of postoperative anterior knee pain, such as the double-incision technique or the bone graft method.^{7,14,15} Tsuda et al.¹⁴ suggested that the use of cored cancellous bone grafting to completely restore donor sites' bony defects and the two-transverse-incision technique can preserve the infrapatellar branch of the saphenous nerve and hence prevent anterior knee pain. Regarding the double-incision approach, it may help to preserve the paratenon and the patellar tendon.¹⁵ In the current study, the authors used autologous bone grafting at both the patella and tibial defects. Moreover, the patellar tendon and paratenon were repaired to improve the healing process in order to reduce the incidence and/or level of anterior knee pain.

A recent meta-analysis conducted by Chee et al.² and comparing the outcomes of BPTB grafts versus 4-strand hamstring autografts found no difference in the rerupture rates of the two groups of autografts. However, the meta-analysis also found significant negative effects in the aspects of anterior knee pain, kneeling pain, and extension deficit that did not support the use of BPTB grafts. The odds ratios of 2.90 (95% CI 1.79–4.70, $p < 0.001$) and 5.63 (95% CI 3.25–9.75, $p < 0.001$) favored the hamstring autograft rather than the BPTB graft for anterior knee pain and kneeling pain. Chee et al.² concluded that the 4-strand hamstring ACL reconstruction has comparable clinical results with the BPTB graft, but with fewer postoperative complications.² However, other studies have found that an ACL reconstruction with a BPTB graft might be superior to a hamstring autograft in restoring rotational stability.^{3,4} Still, the authors prefer using a BPTB graft for young athletic patients who are involved in contact sports.

Our study may be the first to determine and quantify the degree of anterior knee pain for knee activities, especially for kneeling, sitting cross-legged, and sitting one-legged, common knee positions in daily living in Asia. The authors found that kneeling had a higher incidence of anterior knee pain than any other knee activity. Kneeling was also the only activity to produce a considerable level of pain among more than 10% of the patients. Despite that, there was either no, or just mild, pain for the activities of ascending a slope, running, sitting cross-legged, and squatting at the 6-month mark. The overall mean of the VAS pain score of the various activities, excluding kneeling, was less than 3, which was deemed to be a mild level of pain that would not impact on the patients' activities of daily living. For this reason, a BPTB graft remains a good choice for ACL reconstruction, especially in the case of patients who do not engage in kneeling in their daily life.

There are several limitations of this study. Firstly, it had a limited follow-up period of six months. However, the postoperative, accelerated rehabilitation program commenced as soon as possible after the operation; as a result, patients could perform their daily living activities nearly normally within 6 months postoperatively. Additionally, all patients in the study were male and young; female

or older patients might have presented different results.

In conclusion, kneeling was the most troublesome activity in terms of creating considerable levels of anterior knee pain in patients who had undergone an ACL reconstruction using a BPTB graft. Other knee activities, however, did not create moderate or severe degrees of anterior knee pain. Both anterior knee pain and numbness at the proximal leg improved over time.

Conflicts of interest

The author(s) have no conflicts of interest relevant to this article.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.asmart.2018.10.002>.

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