REVIEW

Effectiveness of early quadriceps exercises after anterior cruciate ligament reconstruction

Candice Permall (BSc Physiotherapy)
Alet van Wyk (BSc Physiotherapy)
Anneen van Zyl (BSc Physiotherapy)
Tihanna Vorster (BSc Physiotherapy)
Quinette Louw (BSc, MASP, PhD)

Division of Physiotherapy, Stellenbosch University, South Africa

Abstract

Objective. To systematically review the published information regarding the effectiveness and safety of early post-operative quadriceps muscle exercise training on pain, joint laxity, function and range of motion in postoperative anterior cruciate ligament (ACL) reconstruction adult patients.

Data sources. Five databases (CINAHL, PEDro, Pubmed, Science Direct and the Cochrane Library) were searched for studies published from January 1990 to May 2007.

Study selection. Publications describing research into the effectiveness of early quadriceps exercises after ACL reconstruction were included. A total of three eligible articles met the inclusion criteria.

Data extraction. A review of the three eligible studies was undertaken to describe the key study components. The PEDro Scale was used to determine the methodological quality of the selected trials and the level of evidence of all the eligible studies was categorised according to the evidence hierarchy by Lloyd-Smith.[24] Relevant data were extracted by the two reviewer groups to reduce bias.

Data synthesis. Due to study heterogeneity a meta-analysis could not be conducted. Effect sizes were calculated provided that sufficient data were provided. Outcome measures included range of motion (ROM), functional performance, pain and knee laxity. The methodological quality of the studies did not vary considerably across the studies and the average PEDro score was 66%. Marginal significant differences were noted in knee ROM at 1 month postoperatively, pain day 1 postoperatively, knee laxity and subjective evaluation of function at 6 months postoperatively.

Conclusion. Early quadriceps exercises can be performed safely in the first 2 postoperative weeks, but clinically significant gains in ROM, function, pain and knee laxity were not evident. Further research should include standardised interventions, measurement time frames and outcome measurement tools to allow for a meta- analysis to be conducted.

CORRESPONDENCE:

Quinette Louw
Division of Physiotherapy
Stellenbosch University
P O Box 19063
Tygerberg
7505
South Africa
Tel: 27 21 938 9300
Fax 27 21 931 1252
E-mail: qalouw@sun.ac.za

Introduction

Anterior cruciate ligament (ACL) rupture is one of the most common debilitating knee injuries.[36] This knee injury is commonly sustained by individuals participating in sporting activities that require pivoting, jumping and decelerating actions.[6, 36] Immediately after an ACL injury, the athlete experiences significant functional limitations due to significant swelling and pain.[14,37] Athletes are generally eager to return to their usual level of sporting activity and often also experience psychological distress as the recovery process usually lasts for a few months.[18,37]

The management of an ACL injury may be conservative or surgical.[16,18] However, surgical reconstruction is currently the most common approach in the management of ACL injuries.[8,22,41] The functional outcome after surgical reconstruction appears to be more favourable compared with that of non-surgical management approaches.[1] However, despite advances in ACL repair after reconstructive surgery to optimise the mechanical stability, functional instability of the knee may still be evident in the post-surgery stage.[2]

Physical rehabilitation plays an important role in retraining functional stability of the knee joint after knee surgery.[18] It has also been found that functional rehabilitation was the most important positive prognostic factor for predicting early return to sport.[18] Physiotherapists have the opportunity to select the most appropriate rehabilitation protocol for the specific ACL-injured individual from a range of rehabilitation approaches. Prolific research has been published on rehabilitation protocols after ACL reconstruction.[34] Published research in the 1980s focused on the effectiveness of electrical stimulation of the quadriceps muscle in the acute postoperative stage to decrease the effect of muscle atrophy and weakness.[28] More recently, the focus of published research has been on accelerated versus non-accelerated rehabilitation programmes, as well as open-kinematic chain versus closed-kinematic chain exercises in early rehabilitation after ACL reconstruction.[5,9] Anecdotally, it is proposed that accelerated rehabilitation programmes that allow early range of motion (ROM), immediate weight-bearing and early return to previous functional level should be advocated as best practice. However, these recommendations for best practice are often based on clinical opinion and not on research evidence.[9] Clinical decision-making regarding the most appropriate exercises should be based on research evidence.[9]

Appropriate neuromuscular function of the quadriceps muscle group is required during static and dynamic function of the lower limb.[27] Inadequate quadriceps muscle strength may result in functional instability of the knee joint after ACL injury or reconstruction.[21] Quadriceps muscle weakness is a common sequel after ACL surgery.[40] Quadriceps dyskinesia and weakness follow ACL injury due to neural and physiological changes such as the loss of ACL mechanoreceptor feedback, abnormal gamma loop function of the quadriceps femoris muscle, atrophy of muscle fibres and neural activation deficits.[17,30]

To prevent weakness of the quadriceps muscle and knee extension lag, physiotherapists commonly prescribe quadriceps exercises after ACL reconstruction as early as possible during the inpatient rehabilitation phase.[34] However, given the high costs of surgery and lengthy rehabilitation, the cost-effectiveness of prescribing early quadriceps exercises has been questioned.[34] Furthermore, the safety of early quadriceps muscle strengthening after ACL reconstruction may also be of concern as postoperative anterior-posterior laxity could compromise the integrity of the ACL.[15] Quadriceps muscle contraction produces a rotatory component around the knee joint axis, and also creates a translatory component that causes an anterior shear of the tibia on the femur.[20] The ACL creates an antagonistic pull to resist this anterior shear produced by the quadriceps contraction and by doing so, provides stability to the knee.[20] There is thus strain on the ACL during active quadriceps muscle contraction, mainly in the last 45 degrees of extension, which could compromise the integrity of the graft.[30]

The aim of this review was therefore to systematically appraise the effect of early postoperative quadriceps exercise training on pain, joint laxity, ROM and function, compared with a rehabilitation programme not allowing early quadriceps exercises or restricting quadriceps exercise training to only isometric quadriceps contractions in postoperative ACL reconstruction patients aged between 17 and 44 years.

Methodology

The specific objectives of the review were to:

- describe the type of quadriceps exercises implemented in eligible randomised controlled trials
- describe the outcome measures used to assess pain, knee joint laxity, ROM and function after ACL reconstruction
- assess the effectiveness and safety of early postoperative quadriceps exercise training on pain, joint laxity, function and ROM when compared with a rehabilitation programme not allowing early quadriceps exercises or restricting quadriceps exercise training to only isometric quadriceps contraction in postoperative ACL reconstruction patients aged between 17 and 44 years.

The following definitions were used in this review:

- *Early quadriceps exercises:* Any active lower limb activity aimed specifically at contraction of the quadriceps to achieve full-range knee extension and performed within the first 2 weeks or in the in-patient phase after ACL reconstructive surgery.[32,34,38]
- *ACL reconstruction:* The surgical repair of the ACL after complete ACL rupture or recurrent ligament injury.[10] All types of grafts including bone-patellar tendon-bone, bone-tendon-bone, semitendinosus-hamstring and semitendinosus-gracilis grafts were included in this review.[35]
- *Knee instability:* The lack of physiological anterior-posterior (A-P) and rotational steadiness of the knee joint.[42] Manual clinical tests to evaluate knee instability include the anterior draw, Lachman's and pivot shift tests.[33] The KT-1000 arthrometer is a popular instrument for measuring knee instability.[33]
- *Function:* The ability to safely perform weight-bearing activities including gait, stair climbing and pre-injury function.[21,38] Shaw *et al*. described a number of tests used to assess function, including the single and triple hop tests, timed hop tests, vertical jump tests, stairs hopple test and figure eight running.[33]
- *Pain:* The experience of knee pain as measured with validated pain scales such as the Visual Analogue Scale (VAS).[4]
- *Range of motion (ROM):* The amount of motion, measured in degrees, available to a joint within the anatomic limits of the joint structure.[20] Active and passive range of flexion and extension of the knee can be assessed objectively with a goniometer.[33]

Search strategy

Prior to commencing this project, the Cochrane Library and PEDro were searched to ascertain if a similar review had not been published within the past 5 years. The search findings indicated that a similar review had not been published.

Search strategies were developed for the following computerised bibliographical databases: CINAHL, PEDro, Pubmed, Science Direct and the Cochrane Library. These databases were available via the University of Stellenbosch Library and the World Wide Web. All databases from January 1990 to May 2007 were searched. Each search strategy was developed according to the functions of each database group as follows:

- Group 1: Databases where papers are classified according to their medical subject headings (MeSH) and key terms. These databases allow for terms to be combined (PubMed, CINAHL, The Cochrane Library).

- Group 2: Databases where key terms are used to classify papers. These databases have a limited ability to combine key terms (Science Direct, PEDro).

A detailed search strategy for each of the selected databases was designed. The key search terms were anterior cruciate ligament, ACL, reconstruction, repair, rehabilitation, strengthening, pain, function, exercises. MeSH terms were used in PubMed.

In addition, a secondary search (PEARLing) was conducted by screening the reference lists of all potential full-text articles. To ensure that eligible articles not indexed in the electronic databases were not missed, the authors of the eligible articles were contacted via e-mail.

Eligibility criteria for inclusion

This review included primary research randomised-controlled clinical trials with an acceptable methodological quality appraisal score of at least 4 out of 11 on the PEDro scale.[7] Studies reporting on males and females aged between 17 and 44 years, who underwent unilateral ACL reconstruction of either the right or left knee by the use of any type of graft, were considered eligible for this review. The eligible age was determined by skeletal maturity that is present over the age of 16 years.[36] Articles reporting on patients with common ACL-associated injuries such as medial meniscal injuries were considered eligible since isolated ACL injuries are rare and do not replicate the population of ACL reconstructions generally managed by physiotherapists.

Studies reporting on participants who underwent previous ACL reconstruction on the reconstructed knee, sustained injury to the contralateral knee or presented with any other rheumatological, neurological, cardiovascular or congenital condition that could affect lower-limb function and result in disability, were excluded from this review as they would not reflect the true outcome of this specific intervention.[36]

The interventions of the studies also determined eligibility. Studies that included one treatment group who performed early quadriceps exercises within the first 2 weeks postoperatively and a control group who underwent rehabilitation excluding early quadriceps exercise training or only allowing early isometric quadriceps exercise training were considered eligible for this review.

Eligible studies reporting on the following outcome measures were considered for this review:

- Active range of flexion and extension of the knee as measured with a goniometer.[33]
- Pain experienced as measured with the Visual Analogue Scale or other published validated pain scales.[4]
- Knee stability as measured with the KT-1000 arthrometer or other validated knee-instability scales.[33]
- Lower-limb function as determined by functional tests including the single and triple hop tests, timed hop tests, vertical jump tests, stairs hopple test, figure eight running and other relevant functional tests.[33]

The two reviewer groups screened all hits and selected relevant titles independently. Differences between pairs were discussed until consensus was reached and the fifth author was consulted to resolve any disagreements.

Assessment of methodological quality

In order to determine the internal validity of the eligible trials, the PEDro Scale was used (Table I). The PEDro scale is commonly used in research to critically evaluate randomised controlled trials.[25]

Evidence hierarchy

The level of evidence of all the studies included in this review was evaluated using the evidence hierarchy by Lloyd-Smith.[24]

- 1a: Meta analysis of randomised controlled trials
- 1b: One individual randomised controlled study
- 2a: One well-designed, non-randomised controlled study
- 2b: Well-designed quasi-experimental study
- 3: Non-experimental descriptive studies – comparative/case studies
- 4: Respectable opinion.

Study designs fulfilling the '1b' criteria were considered eligible for inclusion.

Data extraction

The four reviewers were divided into two reviewer groups to extract the data. This was done independently by each of the two reviewer groups. The fifth author was consulted to resolve any discrepancies between the two reviewer groups. The following information was extracted: publication date, authors, journal, study design, setting, PEDro score, aim, description of participants, type of grafts, author's conclusion, clinical relevance, number of participants, description of interventions and outcome measures used.

Data synthesis

The three eligible studies presented heterogeneity with respect to the exercise interventions performed, the outcome measurement tools used and the time frames of measurement. Therefore it was not possible to perform a meta-analysis.

The effect size was calculated with the available data where significant differences between groups were reported by the authors. The effect size represents the clinical magnitude of difference between groups.[29] A greater observed effect represents a larger significant difference.[29] One of the eligible studies, Shaw *et al*. reported sufficient data (mean and SD) to calculate the effect size.[34]

Results

Search results

The results of the search strategy are presented in a flow chart (Fig. 1). Three articles were considered eligible – from Australia, Sweden and Germany.[11,15,34]

Evidence hierarchy

The three selected studies were RCTs, representing level '1b' evidence according to the grading system of Lloyd-Smith.[24]

Methodological quality appraisal

There was 100% agreement between the two reviewer groups regarding the methodological score. The average methodological quality score was 66% (Table I).

TABLE I. Summary of the PEDro scores

PEDro criteria	Shaw *et al*.[34]	Isberg *et al*.[15]	Friemert *et al*.[11]
Eligibility criteria were specified	√	-	√
Subjects were randomly allocated to groups	√	√	√
Allocation was concealed	√	√	-
Groups were similar at baseline regarding important prognostic indicators	-	√	√
Blinding of all subjects	-	-	-
Blinding of all therapists who administered the therapy	-	-	-
Blinding of all assessors who measured at least one key outcome	√	-	-
Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	√	√	√
Subjects for whom outcome measures were available received the treatment or control condition, if not, data for at least one key outcome was analysed by 'intention to treat'	√	√	√
Results of between-group statistical comparisons are reported for at least one key outcome	√	√	√
Provided both point measures and measures of variability for at least one key outcome	√	√	√
Total score	8/11	7/11	7/11

TABLE II. Sample descriptions

	Shaw *et al.*[34]	**Isberg *et al.***[15]	**Friemert *et al.***[11]
Sample size	103	22	60
Surgical procedure	Unilateral arthroscopically assisted ACL reconstruction Graft type : - bone-patellar tendon-bone - semitendinosus-hamstring graft	Unilateral ACL arthroscopic reconstruction Graft type: - patellar tendon autograft	Unilateral ACL reconstruction Graft type: - bone-tendon-bone autograft - quadrupled semi-tendinosus/gracilis autografts
Age of participants	Older than 18 yrs Mean age: 28.6 ± 8.8 yrs	Median (range): 21 yrs (17– 41 yrs)	Mean age: 23 ± 3.6 yrs
Inclusion criteria	All of the above Provided informed consent	No history of injury or any other symptoms of contralateral knee	ACL rupture, IIº - IIIº mechanical instability or clinical giving way sign Age ≤ 35 yrs Healthy contralateral leg
Exclusion criteria	Previous surgery on reconstructed knee (except for arthroscopy) Previous ACL reconstruction on either knee Sustained concurrent injury to contralateral knee Received simultaneous collateral ligament repair Unlikely to attend follow-up	Multiple knee ligament injuries of ipsilateral knee History of previous knee injury or surgery of ipsilateral knee Additional repair of meniscal tears of ipsilateral knee Any knee problems of contralateral knee	Brace treatment Additional knee ligament injuries Contraindications for use of devices Limited ROM due to surgery Neurological and vascular problems/ diseases Post-op infection Injury to hip and/or ankle

TABLE III. A description and comparison of the specific exercise interventions

	Intervention group	Control group	Exercises performed by both groups	Duration of interventions
Shaw *et al.*[34]	Specific quadriceps exercises : • Straight leg raises • Isometric quadriceps contractions (10 x 3 daily)	No specific quadriceps exercises	General exercise programme consisting of: • Foot and ankle exercises • Active assisted knee flexion • Calf stretches • Passive knee extension • Standing posture • Gait education • Passive knee extension with weight	First 2 postoperative weeks
Isberg *et al.*[15]	Full active and passive knee extension between 30° and -10° was allowed, immediately postoperatively	Full active and passive knee extension between 30° and -10° was not allowed, immediately postoperatively, thus restricting active and passive knee extension	Rehabilitation brace and postoperative rehabilitation programme	First 4 postoperative weeks
Friemert *et al.*[11]	Continuous active motion (CAM) of knee flexion and extension	Continuous passive motion (CPM) of knee flexion and extension	Postoperative rehabilitation programme, including isometric strengthening exercises and partial weight-bearing	Day 1 - 7 postoperative

Databases	Initial hits	Accepted titles/ abstracts	Duplicates
CINAHL	*N* = 52	5	17
PEDRO	*N* = 350	20	26
PUBMED	*N* = 298	21	48
SCIENCE DIRECT	*N* = 247	15	13
THE COCHARANE COLLABORATION	*N* = 542	59	12
Total	*N* = 1 489	119	116

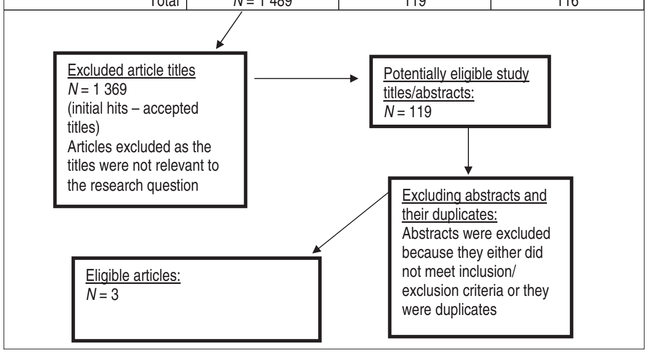

Fig. 1. Results of the search strategy.

Description of study samples

Information regarding participants in each study according to the sample size, age, surgical procedure and inclusion and exclusion criteria was tabulated (Table II). Sample sizes differed across the three studies and the means sample size was 61. The mean age of the samples in the three studies was comparable and none of the studies included participants older than 41 years of age. According to the inclusion and exclusion criteria, all three studies excluded contralateral knee injuries or multiple ligament injuries of the reconstructed knee. A history of previous knee injury or surgery of the reconstructed knee was excluded for Shaw *et al.* and Isberg *et al.*[15,34]

Description of exercise interventions

The exercise programmes performed by the intervention and control group for each of the three studies are described in Table III. The intervention groups of all three studies performed early quadriceps exercises within the first 2 postoperative weeks. The control groups did not perform early quadriceps exercises except for Friemert *et al.*, where only early isometric strengthening exercises were allowed in the first postoperative week.[11]

Description of the outcome measures

The outcomes measures and measurement time frames utilised are summarised in Table IV. Range of motion was the only outcome measure utilised in three studies.

Effectiveness of early quadriceps exercises

The effectiveness of early quadriceps exercise training is presented according to each outcome measure.

Range of motion

Shaw *et al*. measured three ranges over the 6-month follow-up period, namely: active knee flexion, active knee extension and passive knee extension relative to neutral, but the measurement tool was not mentioned.[34] They used mean differences and 95% confidence intervals to determine significant differences between the intervention and control groups.[34] Significant between-group differences (Table V) in active knee flexion and extension 1 month postoperatively were reported. However, it is notable that the lower 95% confidence intervals for both active knee flexion and extension are only marginally significant as they are close to zero. The effect size for knee flexion was 0.44 (medium effect) and 0.48 (medium effect) for extension 1 month postoperatively.

The effect size for active knee flexion in the study by Friemert *et al*. was 0.15 (small effect) at 7 days postoperatively.[11]

Functional performance

Shaw *et al*. objectively evaluated function by means of the functional hop tests consisting of the single-leg-hop and the triple-leg-hop tests (Table VI).[34] Measurements are given as a percentage difference of the reconstructed leg strength relative to the non-operative leg by Shaw *et al*. and Isberg *et al*.[15,34] Shaw *et al*. assessed function 6 months postoperatively and confidence intervals span zero, indicating no between-group significant differences. [34]

Isberg *et al*. objectively evaluated function pre-operatively, at 6 months postoperatively and at 2 years follow-up by means of the single-leg-hop test.[15] No significant differences between the groups were found. The third study by Friemert *et al*. did not report on function objectively.[11]

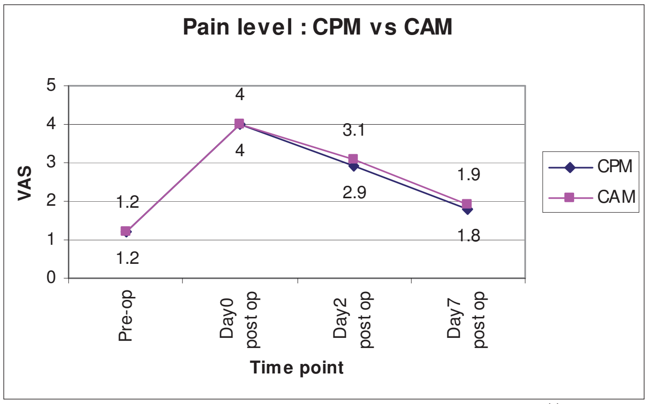

***Fig. 2. Pain as measured by VAS for Friemert* et al.**[11]

Function was subjectively evaluated using outcome measurement scales in two of the studies.[15,34] The Lysholm score, Tegner score and International Knee Documentation Committee (IKDC) evaluation system were used by Isberg *et al*.[15] These measurements were taken preoperatively and at 2-year follow-up. Negligible differences were found between the groups at 2 years.

Shaw *et al*. used the Cincinnati Knee Rating System (CKRS) for subjective assessment of function.[34] The CKRS is a unique rating system that consists of several subdivisions that provide questionnaires for symptoms, function and occupation.[33] The

TABLE IV. Description of outcome measures

Outcome	Study	Outcome measure	Time of measurement									
			Pre-op	Day 0	Day 1	Day 2	Day 7	2 weeks	1 mnth	3 mnths	6 mnths	2-yrs
ROM	Shaw *et al.*[34]	Not explicitly stated			√			√	√	√	√	
	Isberg *et al.*[15]	Standard handheld goniometer	√								√	√
	Friemert *et al.*[11]	Not explicitly stated	√				√					
Function	Shaw *et al.*[34]	Single-hop-test Triple-hop-test									√	
	Isberg *et al.*[15]	Single-hop-test	√								√	√
Pain	Shaw *et al.*[34]	10 cm VAS			√			√	√	√	√	
	Friemert *et al.*[11]	10 cm VAS	√	√		√	√					
Knee laxity	Shaw *et al.*[34]	KT-1000								√	√	
	Isberg *et al.*[15]	KT-1000 RSA	√								√	√

TABLE V. Mean, standard deviation and 95% confidence intervals for ROM measured in degrees

		Active knee flexion Mean (SD)			Active knee extension Mean (SD)			Passive knee extension Mean (SD)		
		Inter-vention	Control	Mean difference (95% CI)	Intervention	Control	Mean difference (95% CI)	Inter-vention	B=Control	Mean difference (95% CI)
Pre-op	Isberg *et al*[15]	No values given.	Isberg *et al.*[15] stated that ROM did not differ between the groups.							
	Friemert *et al.*[11]	139.5 (13.8)	137.5 (16.4)		–	–			–	–
Day 1 post op	Shaw *et al.*[34]	73.8 (20.3)	77.1 (21.6)	-3.3 (-11.5 to 4.9)	-22.5 (8)	-22.4 (7.9)	-0.1 (-3.8 to 3.6)	-12.7 (6.4)	-11.8 (6.1)	-0.9 (-3.6 to 1.8)
Day 7 post op	Friemert *et al.*[11]	101 (17)	95 (14)		No values given but Friemert *et al.*[11] stated that all patients reached full extension at this point in time.			–	–	
2 weeks post op	Shaw *et al.*[34]	104.9 (15.3)	101.8 (15)	3.1 (-3.4 to 9.6)	-16.5 (6.1)	-19.2 (6)	2.7 (-0.1 to 5.5)	-9 (5.4)	-9 (5.6)	0 (-2.4 to 2.4)
1 mnth post op	Shaw *et al.*[34]	128.2 (12.7)*	122.3 (14.5)*	5.9 (0.1 to 11.7)*	-12.1 (4.8)*	-14.8 (6.4)*	2.7 (0.1 to 5.3)*	-6.5 (4.2)	-7.7 (5)	1.2 (-0.8 to 3.2)
3 mnths post op	Shaw *et al.*[34]	138.9 (8.1)	139.9 (8)	-1 (-4.5 to 2.5)	-7.4 (4.4)	-7.7 (4.5)	0.3 (-1.8 to 2.4)	-4.2 (3.7)	-3.8 (3.1)	-0.4 (-1.9 to 1.1)
6 mnths post op	Isberg *et al.*[15]	No values given. Isberg *et al.*[15] stated that ROM did not differ between the groups								
	Shaw *et al.*[34]	141.6 (6.9)	142.6 (7.6)	-1 (-4.1 to 2.1)	-5.7 (4.1)	-4.9 (4.2)	-0.8 (-2.7 to 1.1)	-3.1 (3.4)	-2.3 (3.2)	-0.8 (-2.2 to 0.6)
2 yrs follow-up	Isberg *et al.*[15]	No values given	No values given		No significant difference between groups when comparing the intact and reconstructed knee for each individual patient			–	–	

\- = no measurement taken.
* significant difference ($p<0.05$).

measures were taken at 1, 3 and 6 months postoperatively. At 6 months postoperatively, statistically significant differences between the groups were demonstrated for the subdivision 'Problems with Sport'. The intervention group had a higher (more favourable) score than the control group for the 'Problems with Sport' category (Table VII). However, the 95 % CI spans 0 and the effect size we calculated were 0.33, indicating that the effect of the early quadriceps exercises was small.

Pain assessment

According to Shaw *et al*. there was no statistically significant difference between the groups for pain perception at any follow-up intervals (Table VIII).[34] However, in the quadriceps exercise group, significantly greater pain with exercise performance was measured on the first post-operative day.

Findings of the studies conducted by Friemert *et al.* did not demonstrate significant differences in preoperative pain measurements on the operative day and on the second and seventh day postoperatively (Fig. 2).[11] Isberg *et al*. did not report on pain as an outcome measure.[15]

Shaw *et al*. further evaluated pain by means of die CKRS evaluation system.[34] Six months postoperatively the intervention group reported significantly higher (more favourable) results for pain calculated under the CKRS subdivision 'Symptoms' (Table IX). However, the lower confidence interval is marginally significant (0.2). The effect size calculated as 0.62, indicating that the early quadriceps exercises had a moderate on pain perception.

Knee laxity

Shaw *et al.* measured A-P laxity by means of the KT-1000 using a 15-pound, 20-pound and maximal manual test force.[34] Measurements, presented in Table X, were taken 3 and 6 months postoperatively. A-P side-to-side differences of greater than 3 mm or greater than 5 mm were used as cut-off points during testing as these were seen as indications of abnormal laxity. For each test force, Shaw *et al*. retrieved the number of abnormally

TABLE VI. Results of functional tests – a quotation (%) between the intact and the injured knee

		Single-leg-hop			Triple-leg-hop		
		Intervention	Control	Mean difference (95% CI)	Intervention	Control	Mean difference (95% CI)
Pre-operative	Isberg *et al.*[15] Median (range)	82 (0-96)	80 (0-96)		Not measured	Not measured	
6 mnths	Shaw *et al.*[34] Mean (SD)	83.8 (10.1)	81.7 (12.7)	2.1 (-2.8 to 7)	83.7 (11.4)	81.8 (13.6)	1.9 (-3.5 to 7.3)
24 mnths	Isberg *et al.*[15] Median (range)	97 (86-100)	96 (85-100)		Not measured	Not measured	

TABLE VII. Function as measured with CKRS 'Problems with Sport' category (Shaw *et al.*[34])

	Intervention Mean (SD)	Control Mean (SD)	Mean difference (95% CI)
1 mnth post op	40.2 (11.6)	41.6 (11.9)	-1.4 (-6.2 to 3.4)
3 mnths post op	55.2 (12.5)	51.2 (12.4)	4 (-1.2 to 9.2)
6 mnths post op	66.4 (14.4)*	61.6 (15.2)*	4.8 (-1.4 to 11)*

*$p<0.05$.

lax knees and compared this with the number of subjects measured.[34] The total number of subjects presenting with lax knees were calculated with the available data. The control group demonstrated a significantly greater number of subjects with laxity at each test force 6 months postoperatively. No significant differences were noted 3 months postoperatively.

Isberg *et al*. used the KT-1000 and radiostereometric analysis (RSA) to evaluate AP laxity preoperatively, 6 months postoperatively and at 2-year follow-up.[15] No significance between group differences was found at any point of measurement. However, there was a statistically significant reduction in A-P laxity within each group from the pre-operative period until the 2-year follow-up (Table XI).

Discussion

This paper reports on the effectiveness of early quadriceps exercise after ACL reconstruction and illustrates the sparse literature available to determine the effect of this common physiotherapeutic intervention in this patient intervention. Physiotherapists commonly prescribe static isometric quadriceps exercises early postoperatively, with the aim of restoring neuromuscular function of this muscle as soon as possible.[34] However, the findings of this paper demonstrate that this usual practice procedure may not apply to all patients and requires reconsideration.

The three eligible papers had common methodological limitations. All three studies have not met the blinding of subjects and therapists criterion. Blinding of therapists and patients in exercise intervention studies is impossible in the majority of trials as the therapists and patients can often differentiate between intervention and placebo exercises for a specific patient population.[12] Therefore, although there was heterogeneity with respect to sample size, exercise interventions, outcome measurement and data analysis, the methodological quality of the studies is comparable. The methodological quality of the studies was deemed acceptable, evidenced by the critical appraisal findings and therefore the internal validity is considered to be sound. However, since all the trials were conducted at one conveniently selected clinic, the external validity of the studies may be limited. Furthermore, only one of the studies indicated that a sample size calculation was conducted.[11] The range of the sample sizes was 22-103 participants among the three studies and, according to Shaw *et al*., were relatively small when compared with the number of ACL reconstructions performed internationally.[34] A larger sample size is likely to be a more accurate representation of a population and will thus produce more recognisable between-group statistically significant differences.[29] Therefore the power of the remaining two studies has not been indicated, highlighting the limitations with respect to external validity of the findings.

The age of participants ranged from 17 to 41 years in the three selected studies. Adolescents and young adults who are physically active in sports are usually at an increased risk of an ACL injury.[24] Therefore the age group of subjects represents the high-risk group for ACL injuries.[6,24,36] The descriptions of the samples, however, lack specific information about the level and type of sporting activity, which may reflect different levels of motivation to engage in exercise therapy and return to sporting activity. A few months' absence from competition and sport may result in detrimental socio-economic consequences for professional athletes,[31] who are usually more motivated to commence their rehabilitation process at an earlier stage compared with recreational athletes or sedentary individuals. It may therefore be important to assess the outcome of this early exercise intervention within patient populations with a specific level of sporting activity as the psychological benefits of early rehabilitation may be advantageous in competitive athletes.

The outcomes measurement tools used in the selected studies were valid and reliable.[13,19] The goniometer, KT-1000, visual analogue and functional hop tests are valid and reliable outcome measures according to the findings of a published systematic review.[33] According to Isberg *et al*. the radiostereometric analysis (RSA) is a reliable and valid outcome

TABLE VIII. Pain as measured with VAS (Shaw *et al.*[34])

	Pain at rest			Pain on performing exercise		
	Intervention Mean (SD)	Control Mean (SD)	Mean difference (95% CI)	Intervention Mean (SD)	Control Mean (SD)	Mean difference (95% CI)
Day 1	3.1(2.2)	2.6(2)	0.5 (-0.3 to 1.3)	6.9(2)*	6(2.1)*	0.9 (0.1 to 1.7)*
2 weeks	2.5(1.7)	2.2(1.9)	0.3 (-0.4 to 1)	5.9(1.9)	5.2(2.1)	0.7 (-0.1 to 1.5)
1 month	0.9(0.8)	0.9(1.1)	0 (-0.4 to 0.4)	3.5(2)	4(2.3)	-0.5 (-1.4 to 0.4)
3 months	0.4(0.7)	0.5(0.7)	-0.1 (-0.4 to 0.2)	3.1(2)	2.8(2.1)	0.3 (-0.6 to 1.2)
6 months	0.3(0.6)	0.3(0.6)	0 (-0.3 to 0.3)	2(1.9)	2.1(1.8)	-0.1 (-0.9 to 0.7)

*significant results ($p<0.05$).

TABLE IX. Pain as measured with CKRS (Shaw *et al.*[34])

	A Mean (SD)	B Mean (SD)	Mean difference (95% CI)
1 mnth post op	4.9 (1)	4.8 (1)	0.1 (-0.3 to 0.5)
3 mnths post op	6.1 (1.1)	6.2 (1.2)	-0.1 (-0.6 to 0.4)
6 mnths post op	7.5 (1.2)*	6.8 (1.1)*	0.7 (0.2 to 1.2)*

A = intervention group
B = control group
* significant results.

measure.[15] However, differences in outcome measurement time frames and interpretation did not allow for a meta-analysis of the outcome data. Shaw *et al*. recommended that key outcome measures should be used at specific time frames postoperatively, in order to optimise the sensitivity of these measuring tools and thus enhance its validity and reliability.[33] Future research in this field should attempt to identify the most appropriate outcome measurement type and measurement time frames after ACL reconstruction.

Appropriate descriptions of the exercise intervention regimens were presented in the selected studies. This is a positive aspect of the reviewed papers, as a clear description of interventions is often lacking in physiotherapeutic trials. Poor descriptions of the interventions make it difficult or impossible to apply effective interventions based on robust research evidence. The exercise interventions applied in the papers were mostly representative of usual clinical practice.[32] The findings of this review are therefore relevant to clinicians who prescribe similar exercise regimens as they provide insight into the effect on patient outcomes.

TABLE X. A-P laxity at 6 months (Shaw *et al.*[34])

KT-1000 test force	A-P laxity	A Number of subjects with laxity (*N*)	B Number of subjects with laxity (*N*)	*p*
15 lb	3 mm	3 (47)*	12 (44)*	0.01*
15 lb	5 mm	0 (47)	2 (44)	
20 lb	3 mm	10 (47)	13 (44)	0.36
20 lb	5 mm	1 (47)	7 (44)	
Max manual	3 mm	17 (47)	16 (44)	0.99
Max manual	5 mm	1 (47)	9 (44)	
Total number of subjects presenting with lax knees		32*	59*	

A-P laxity: An anterior-posterior side-to-side difference of greater than 3 mm or greater than 5 mm on testing with the KT-1000 arthrometer.
* significant difference ($p<0.05$)
A = intervention group
B = control group.

TABLE XI. A-P laxity preoperatively, at 6 months and 24 months follow-up (Isberg *et al.*[15])

	RSA		KT-1000	
	Intervention Median (range) in mm	Control Median (range) in mm	Intervention Median (range) in mm	Control Median (range) in mm
Preoperative	8.6 (2.3-15.4)	7.2 (2.2-17.4)	2.0 (0-8.0)	4.0 (0-10.10)
6 mnths	3.4 (0.6-11.5)	3.4 (-3.3 to 7.8)	0 (-3.0 to 1.5)	1.5 (0.5 to 4.5)
24 mnths	2.7 (0-10.7)	2.8 (-1.8 to 9.5)	1.0 (-1.5 to 3.5)	0.5 (-1.0 to 4.0)
Preop v. 24 mnths	p=0.005	p=0.005	p=0.0096	p=0.004

A-P laxity: An anterior-posterior side-to-side difference of greater than 3 mm or greater than 5 mm on testing with the KT-1000 arthrometer.
■ = significant difference ($p<0.05$).

Appropriate function of the quadriceps muscle group is important daily and sporting activities.[27] These review findings indicate that no significant difference in functional performance was noted between the intervention and control group 6 months and 24 months postoperatively. Objective functional performance was not assessed before 6 months due to precautionary limitations related to the surgery. There was no difference between groups with respect to most of the subjective functional scale findings. However, a significant difference for the 'problems with sport category' was reported by Shaw *et al*., but the effect size indicated that the clinical effect was small.[34] The finding indicated that the intervention group experienced significantly more pain when exercising, and this may contribute further to inhibit quadriceps muscle contraction.[3,34] The improvement in muscle function when performing early quadriceps exercises may thus be relatively small and it appears that functional use of the quadriceps muscle performed when the patient's pain experience is tolerable may be appropriate to produce appropriate strength required for function. A clinical recommendation may thus be that pain may need consideration when prescribing these exercises.

Shaw *et al*. reported that the subjects in the intervention group had marginally better improvement in active knee flexion and extension ROM, but this was limited to 1 month postoperatively.[34] However, the effect size indicated a medium clinical effect of range of motion at 1 month. According to Milne *et al*. a minimum of at least 90˚ of flexion is required to safely descend stairs and 105˚ to rise from a toilet seat.[26] However, since both groups achieved these functional range requirements, the clinical effect of the range of motion findings by Shaw *et al*. is questionable.[34]

There is concern that early quadriceps exercises may result in increased anterior-posterior knee laxity, resulting in damage to the graft.[15] Shaw *et al*. concluded that the prevalence of knee instability 6 months postoperatively was reduced by performing early quadriceps exercises.[34] However, Isberg *et al*. reported no significant difference between groups 6 months postoperatively.[15] Shaw *et al*. incorporated a larger sample size and may be representative of the ACL injury population.[29,34] A more notable finding was that A-P laxity was not different between the intervention and control groups in the long term.[34] This may indicate that early quadriceps exercises can be considered safe in this population as they did not compromise stability.

Limitations

In this review, only studies reported in the English language were considered eligible due to time and resource constraints. In the case of uncertainty regarding information presented in the studies, authors were contacted via e-mail. However, if they did not reply, contact was not made telephonically due to resource constraints. Heterogeneity of the data of eligible studies did not allow for a meta-analysis to be conducted.

Conclusion

Early quadriceps exercises do not compromise the integrity of the graft, as they do not increase ligament laxity. However, it appears that the gains when performing early quadriceps exercises or restricting quadriceps exercise training to only isometric quadriceps exercises with respect to range of motion and function are small or insignificant. Further research is required and should include standardised interventions, measurement time frames and outcome measurement tools to allow for meta-analysis of the data.

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ORIGINAL RESEARCH ARTICLE

A conservative programme for treatment of anterior knee pain in adolescents

Jacqueline Phillips (BSc Hons Biokinetics)
Marius F Coetsee (PhD)

Department of Human Movement Science, University of Zululand, KwaDlangezwa

Abstract

Objective. The purpose of this study was to determine the effectiveness of a 2½-week conservative rehabilitation programme in addressing anterior knee pain in adolescents.

Design. Subjects were randomly allocated to a control group (*N*=12) and an experimental group (*N*=18). The experimental group was subjected to a 2½-week strength, flexibility and neuromuscular rehabilitation programme. Both groups were tested before and after the 2½ weeks and the experimental group also 1 month after the post-test.

Results. The experimental group reported significant (p<0.01) improvement in pain (Visual Analogue Scale), disability (Patient-Specific Functional Scale) and condition (Scale for Change in Condition). The experimental group tested significantly (p<0.01) better for strength (quadriceps and hamstrings), flexibility (quadriceps, hamstrings and gastrocnemius) and neuromuscular control (Willknox wobble board and Bass test of dynamic balance). The control group experienced no improvement in any of the tests.

Conclusions. The 2½-week rehabilitation programme for addressing anterior knee pain in adolescents proved to be effective. The study demonstrated good retention of improvements and even further improvement after cessation of the programme. Advantages are the short duration and the fact that patients are familiarised with a home programme which they are likely to continue with. Although not addressed in this study, literature indicates that restoration of neuromuscular control might be the main contributing factor for the success of the programme.

CORRESPONDENCE:

Professor MF Coetsee
University of Zululand
Private Bag X1001
KwaDlangezwa
3886
Tel: 27 35 772-6639
E-mail: mcoetsee@absamail.co.za

Introduction

Anterior knee pain is a common condition that affects a wide age range of patients.[5] The condition is often self-limiting, but can take up to 2 years to resolve.[16] It frequently interferes with exer-