

## Short Communication

# Sphygmomanometer as biofeedback in acute anterior cruciate ligament reconstruction rehabilitation: A cost-effective technique

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## Abstract

Quadriceps dysfunction following anterior cruciate ligament reconstruction (ACLR) is a common threat to any sports rehabilitation. Even though the role of biofeedback (BFB) and neuromuscular electrical stimulation has been in use to preserve the quadriceps in the acute phase of ACLR, this paper focuses on retraining the same using a sphygmomanometer as pressure BFB. A 25-year-old male collegiate with an isolated tear of ACL was followed up from immediate postoperative period to the outpatient care services for 3 months. The isometric quadriceps pressure difference and heel height difference were measured initially and reevaluated following the intervention. Relearning of impaired quadriceps following an ACLR depends on the response, and so the accurate dose-response in the form of pressure BFB using sphygmomanometer reduces the financial constraints of a sophisticated BFB unit. It provides an easy understanding of the quality and the magnitude of the exercise.

**Key words:** Anterior cruciate ligament, isometric quadriceps pressure difference, reconstruction, sphygmomanometer

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## INTRODUCTION

Quadriceps inhibition<sup>[1]</sup> is a common threat in acute rehabilitation phase of anterior cruciate ligament reconstruction (ACLR),<sup>[2]</sup> as ACLR is followed by immobilization and reduced activity that results in quadriceps atrophy and adhesion formation. Although exercise intervention plays a major role in overcoming this concern, weak quadriceps continues to pose a challenge in initiating the rehabilitation protocol since these conditions can limit the ultimate recovery of knee strength and range of motion. Many authors have highlighted and widely discussed the role and effectiveness of electromyography biofeedback (EMG-BFB)<sup>[3,4]</sup> and neuromuscular electrical stimulation (NMES)<sup>[5-8]</sup> in the acute rehabilitative phase for improving quadriceps contraction following ACLR procedures for regaining muscle control. However, difficulty and challenges in the early postoperative phase exist due to the diminished activity of joint receptors,

and the feedback from these receptors influences the activation of motor units. Therefore, any disturbance in the receptor feedback mechanism due to tissue trauma in the anterior capsular incision in ACLR procedures, may not be regained in the acute phase which can interfere with patients ability and progression in the later part of the rehabilitation. As a result of loss of these facilitatory effects, there is a diminished control and use of quadriceps muscle in the early part of routine rehabilitative exercise protocols. The focus of rehabilitation commonly used is designed to facilitate muscle performance without imposing damaging stress on the graft site.

Use of electrical stimulation in improving quadriceps has also been proven to be effective than the routine

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conventional exercise regimen in the early phases of rehabilitation.<sup>[9]</sup> BFB in any form can be a suitable augmentor of receptor feedback and also serves as an immediate, precise, and concurrent source of information to the patient. Although the patient may not be oblivious to the muscle activity, they can see the results of the efforts. Use of EMG-BFB in recovering and relearning the quadriceps function following ACLR has found to be significant, particularly when the patient is unable to execute a maximal contraction<sup>[10]</sup> and also facilitates the recruitment of vastus medialis which helps to regain full extension.<sup>[3]</sup> It has been found that BFB has an advantage in facilitatory feedback response along with neural changes in quadriceps than electrical stimulation.<sup>[10]</sup>

A modified sphygmomanometer was utilized in measuring the strength of shoulder and hip manually and was found to be a very reliable measuring device.<sup>[11]</sup> BFB using a pressure sensor from a stabilizer was advocated in successfully recruiting the deep neck flexors in the treatment of cervicogenic headaches.<sup>[12]</sup> Where the flattening of the cervical curvature was sensed from the cuff and subsequently measured in the pressure gauge. The objective of this study is to apply the principles of pressure feedback measured directly by the effort of quadriceps contraction and reeducate the muscle in the immediate postoperative ACLR using a cost-effective, simple operating gadget, to quantify the progress and to maintain the isometric strength of quadriceps.

## MATERIALS AND METHODS

### Report of the case

A 25-year-old male college student with bone patellar tendon bone graft transfer for an isolated right ACL rupture was taken up for the case study. There was ipsilateral relative quadriceps atrophy in the postoperative period and a knee extension deficit of 30°. This case was taken from the Department of Orthopedic Surgery ward from postoperative day 7 and later followed up by physiotherapy outpatient care services for a period of 6 months; a verbal consent was obtained to publish the data.

### Examination

On observation, the individual showed atrophy of vastus medialis with a proportional difference in girth of about 2 cm and 1 cm at the thigh and the calf, respectively. There was an inhibition pattern in quadriceps activity and presented with mild to moderate pain with the knee positioned in minimal flexion attitude.

As the focus of attention was on retaining the quadriceps function, isometrics regimen were prescribed and followed up on routine basis, despite the patient was

finding it difficult to reinforce and establish the adequate pressure needed for reeducation. Therefore, a modality to measure and monitor the pressure applied became the necessity of the hour which can reassure a progressive and an accurate reeducation of quadriceps function without disturbing the graft healing.

A conventional sphygmomanometer was used with cuff tightly wrapped over a 500 ml polyethylene terephthalate bottle filled with water; the cuff was inflated to about 80–100 mm/Hg [Figure 1]. The individual was positioned in long sitting with hand supported and ipsilateral knee placed approximately in 10–15° of flexion angle [Figure 2].

### Procedure

The designed apparatus was placed under the contralateral knee of the subject and was instructed to perform isometric quadriceps contraction with a hold time of 5–8 s under therapist supervision to avoid potential compensation patterns such as pelvic hiking, excessive hamstrings, and gluteus maximus activity.

The base pressure was fixed and maintained at about 100 mm/Hg in the sphygmomanometer, and the pressure difference was noted following isometric quadriceps contraction.

The isometric quadriceps pressure (IQP) on the normal side was found to be 90 mm/Hg. The same procedure was repeated on the operated side, and the IQP was measured to be 20 mm/Hg. The difference in IQP (IQPD) was 70 mm/Hg [Table 1]. The patient was instructed to observe and maintain the values throughout the procedure [Figure 3].

A power building protocol model based on De Lorme's exercise regime of progressive and gradual loading of weak quadriceps was designed with the initial target of 25% of the total IQPD for 25–50 repetitions, 2–3 sessions per day for the 1<sup>st</sup> week, whereas the subsequent weeks were targeted with 50%, 75%, and 100% [Table 2]. The repetitions were progressively increased.

This Delorme's progressive resistive exercise, routine rehabilitation protocol for ACLR was followed, and the appropriate intervention to the corresponding time frame was introduced and carefully monitored.

**Table 1: Baseline parameters**

Outcomes	Right	Left	Difference
Girth (cm)			
Thigh	36	38	2
Calf	25	26	1
Strength (mm/hg)			
IQP	20	90	70
Knee flexion deformity (inches)			
HHD		3	

IQP: Isometric quadriceps pressure, HHD: Heel height difference



Figure 1: Sphygmomanometer as pressure biofeedback unit



Figure 2: The unit is placed under the knee and the procedure is carried out with hips and ankle in contact to the couch while the trunk is inclined with hand support

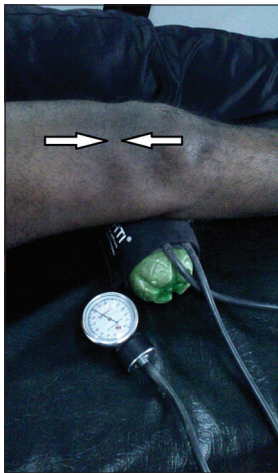


Figure 3: Deflection during isometric quadriceps contraction



Figure 4: Measurement of heel height difference

The isometric strength training regimen with the sphygmomanometer was employed in the initial period of rehabilitation to achieve a benchmark in normal functioning of quadriceps with a near normal side-to-side ratio and was maintained with thorough monitoring.

Knee flexion deformity was measured using heel height difference (HHD) which was measured with the patient lying in prone at the end of the couch with thighs supported and the legs extending out. The examiner measures the difference in the heel height [Figure 4].

## RESULTS

The initial net IQPD measured at the end of the 2<sup>nd</sup> week was 20 mm/Hg, and the HHD was noted to be 3 inches. The HHD reduced gradually by  $0.5 \pm 0.3$  inches as the net IQPD increased by  $10 \pm 5$  mm/Hg

Table 2: Progressive isometric quadriceps pressure difference training protocol

Period (weeks)	IQPD (%)	Repetitions	Sessions (/day)
I-III	25	25-50	2-3
III-VI	50	25-75	3-4
VI-XII	75-100	75-100	4-5

IQPD: Isometric quadriceps pressure difference

Table 3: Outcome measures

Period (weeks)	IQPD mm/hg	HHD (inches)
II	20	3
IV	25-30	2.8
VI	30-40	2
VIII	40-55	1.5
XII	55-75	<1

IQPD: Isometric quadriceps pressure difference, HHD: Heel height difference

every 2 weeks. At the end of 3 months, the IQPD on the right side was 75 mm/Hg and the HHD was <1 inch [Table 3].



## DISCUSSION

It has been demonstrated that a BFB for an isometric effort responded significantly in postoperative knee rehabilitation.<sup>[3,4]</sup> When an individual is trying to relearn the motor activity and regain his maximal original isometric strength of impaired quadriceps, the usage of a conventional sphygmomanometer can be on par with BFB and NMES in rehabilitation of ACLR. Since learning has been defined as a beginning to change and becomes complete when the change is established and imprinted. For a proper learning to take place, an accurate response for a given input of effort is mandatory.<sup>[10]</sup> It becomes necessary on the part of the physical therapist to ensure and reinforce the accuracy of the response initiated.

Pain and swelling are the markers for quadriceps dysfunction in immediate postoperative ACLR.<sup>[1]</sup> Muscle inhibition is thought to occur either by failure of central motor drive to recruit all available motor units in the muscle or by reducing the maximal discharge rate of contraction of motor units. This proposed reduction in central motor drive may be caused by an ongoing reflex inhibition secondary to joint distension or damage.

The underlying neurophysiology of quadriceps weakness is numerous, and one of the theories which are widely discussed is that of central activation deficits (CAD). The role of NMES can be crucial in attenuating the ill effects of CAD in promoting the reactivation of normal quadriceps function<sup>[13]</sup> by activating a greater proportion of type 2 muscle fibers than voluntary contraction. However, to produce a sufficient force and strength in the muscle, the intensity of the current has to be increased proportionately<sup>[14]</sup> which in turn depends on the individual's tolerance level. Hence, the patient's tolerance level stands as a critical limitation to the application of NMES in post-ACLR.

Quadriceps weakness is a common phenomenon in any postoperative condition.<sup>[2]</sup> In specific, the rehabilitation guidelines of ACLR have highlighted the importance of gaining early normal quadriceps strength and its impact in the later part of the rehabilitation module.<sup>[2]</sup> When an NMES and BFB are being deployed, the technical and financial constraints have to be duly considered, and above all the patient levels of cooperation and the compliance have to be taken into account for a successful outcome. In this study, the pressure difference noted in the apparatus provides the patient a user-friendly way to monitor accurately the maximal volumetric contraction ability of quadriceps. High-intensity rehabilitation can produce greater quadriceps strength in the initial phase of recovery following ACLR and ensures a lower CAD compared to low-intensity rehabilitation.<sup>[13]</sup>

This study utilized the pressure BFB<sup>[15]</sup> from the cuff wrapped around the bottle and strapped. This method was safe and accurate in measuring varied muscle groups. It was also discussed in the evaluation of deep neck flexors strength<sup>[16]</sup> in cervical pathologies, shoulder and hip muscle strength,<sup>[11]</sup> hand grip strength evaluation,<sup>[17]</sup> and also a combined multimodal approach of low load exercises was found effective in muscle performance, and there was a spontaneous return of muscle function. With the advocacy of the trial suggesting that the afferent input enabling perception in pain modulation, Jull in his work on cervicogenic headaches has discussed the effectiveness of specific low load exercise program which may be suggestive in stimulating neural inhibitory systems at various levels in the spinal cord and may also activate descending inhibitory pathways. Furthermore, it was also discussed that a reduction in electrical activity as a response could be achieved through reciprocal relaxation with exercises of deep neck flexors. This modified application of sphygmomanometer in the evaluation of isometric quadriceps strength has been documented and validated<sup>[18]</sup> long back, but the interrater reliability for the same was questionable. Hence, the usage of this conventional apparatus in maintaining and improving quadriceps isometric strength in postoperative ACLR may stand useful.

In this study, use of conventional sphygmomanometer made the individual more conscious of the quality and the magnitude of the muscle contractions during the exercise routine, and hence, it was easy to set the desired goal to achieve more consistent outcome values during the initial phases of recovery, in particular when the terminal active extension is not encouraged in early phase of ACLR.

It was also evident in this study that with the early introduction of a sphygmomanometer in the immediate postoperative phase of rehabilitation, there was an enhanced knee extension range apart from maintaining the optimal voluntary isometric quadriceps strength. As subtle knee flexion contracture is a common complication following ACLR, it may be difficult to detect using standard goniometric methods. For this reason, we have used the HHD, which is a reliable indicator for subtle knee flexion contracture.<sup>[19]</sup> On correlating the positive relationship between IQPD values to HHD, it was noticed that in the later period, the individual's IQPD was reducing proportionately with respect to the reduction in HHD values, this demonstrated that there was a steady decline of HHD values over a period of time and was almost nil at the end of 10–12 weeks post-ACLR.

It was also evident that usage of sphygmomanometer was not only therapeutic but can also be used as a valid diagnostic tool in evaluating the quadriceps strength accurately to facilitate the therapist in progression, to the subsequent phases of ACL rehabilitation where the strength

index of quadriceps is an important benchmark. During the course of follow-up in this study, the IQP values were almost equal to opposite side and the apparatus was used more as a monitoring device than an interventional gadget.

Improper inflation and variation in the valve pressure can sometimes lead to error in measurement. Lifting the ankle during the maneuver can become an isotonic measurement, so proper instructions and supervision become inevitable. Therefore, this procedure may be adopted in other postoperative knee conditions, inflammatory, and degenerative arthritic knee conditions which do not warrant mobilization.

## CONCLUSION

Conventional sphygmomanometer could be a useful alternative in monitoring and maintaining the isometric quadriceps strength during acute phase of post-ACL reconstruction rehabilitation. This methodology can be affordable both on the part of the physical therapist in a general practice setup and also to the patient who can continue the quality regimen on a regular home care basis. The validity and reliability of this gadget in quadriceps isometric strength warrant further study in a larger and a varied population.

### Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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### Conflicts of interest

There are no conflicts of interest.

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