

The Use of a Weight-Bearing Biofeedback System as an Adjunct in Rehabilitation Following a Simultaneous Bilateral Anterior Cruciate Ligament Reconstruction: A Case Study Report

Yonatan Kaplan* and Noa Spieler

Lerner Sports Center, Hebrew University of Jerusalem, 1 Churchill St., Mount Scopus, Jerusalem, IL, Israel

Abstract

Background: Despite the plethora of published articles relating to anterior cruciate ligament injuries, little evidence exists regarding the subject of simultaneous bilateral anterior cruciate ligament reconstruction (SBACLR) and its rehabilitation challenges.

Case Report: This case study presents a 17-year-old female athlete who underwent a rare surgical procedure: a SBACLR and suturing of the medial collateral ligament of one knee. A relatively new innovative computerized air-insole auditory biofeedback system (Smartstep™) was used as an adjunct in the evaluation and promotion of weight-bearing in the early stages of rehabilitation.

Results: Following intensive rehabilitation over a seven-week period, the athlete progressed in all functional activities of daily living, with a gradual bilateral improvement in weight-bearing abilities. After completion of her rehabilitation program, she returned symptom-free to all previous functional and sporting activities.

Conclusions: This case study highlights the fact that although a SBACLR is still a relatively uncommon knee surgical procedure, the possibility exists for an athlete to return to full functional activities of daily living. The Smartstep™ system proved to be a useful objective and accurate adjunct during the rehabilitation process.

Keywords: Knee; Anterior cruciate ligament reconstruction; Weight-bearing; Biofeedback

Abbreviations: ACL: Anterior Cruciate Ligament; ACLR: Anterior Cruciate Ligament Reconstruction; SBACLR: Simultaneous Bilateral Anterior Cruciate Ligament Reconstruction; MCL: Medial Collateral Ligament; LQF: Lysholm Questionnaire Form; TALS: Tegner Activity Level Scale; IKDC: International Knee Documentation Committee

Introduction

One of the more common injuries in sports that involve sudden directional changes is the rupture of the anterior cruciate ligament (ACL) within the knee. Patients who have bilateral ACL-deficient knees are occasionally seen in a sports medicine practice. Despite reports of simultaneous bilateral ACL ruptures in the literature, the vast majority of patients presenting with bilateral ACL deficient knees sustain no simultaneous bilateral ACL ruptures [1]. ACL injury occurs four to six times more frequently in women than in men who had participated in the same sporting activity, a phenomenon that is well-supported by the literature [2,3]. The reasons postulated for this difference include neuromuscular, hormonal and anatomical factors [4,5].

Without anterior cruciate ligament reconstruction (ACLR), there tends to be a significant increase in the risk for further meniscal damage [6] and a decrease in the proprioceptive function of the knee joint [4]. The rehabilitation process following ACLR ranges between four to six months [7]. In the case of a bilateral ACL tear, where the reconstruction is carried out on each knee separately, the athlete will be unable to return to play for approximately a year. The incidence of bilateralism is reported to be between two and four percent of ACL-injured knees [1,8]. ACLR results in changes in lower extremity joint kinetics, including in the normal gait pattern [9]. These changes include an abnormal lower leg movement pattern, a stiffening strategy of the knee and a reduced knee range of movement [9-12].

There is no consensus regarding the optimal rehabilitation protocol following ACLR and many varying protocol paradigms have been proposed [13,14]. The authors conducted a literature search of

all articles written in English. Six articles were found that discussed the subject of simultaneous bilateral anterior cruciate ligament reconstruction (SBACLR) [1,15-19]. One study, [17] reported on a case series of eight patients who underwent simultaneous bilateral ACL reconstruction. The authors concluded that when there is a need to perform this type of operation, it is a safe and clinically effective option that is time and economically sound. The most recent prospective comparative study compared the mid-term outcome of 7 patients (14 knees) who had one-stage bilateral ACL reconstruction with that of a matched group of patients who had unilateral reconstruction (21 patients). Their mid-term clinical results suggested that one-stage bilateral ACL reconstruction using either hamstring or patella tendon autograft is clinically effective, reproducible, cost effective and does not compromise functional results. Both these studies had very small patient cohorts and their follow up period was limited, so no long term conclusions may be drawn. Little detail was provided related to the rehabilitation protocol used in the studies.

Asymmetric gait patterns persist up to one year post-ACLR and are more pronounced during stair ascent and descent than in level walking. These results indicate that clinicians should include specific interventions aimed at improving knee function during stair use in order to restore normal function after ACLR [20]. It may take up

***Corresponding author:** Yonatan Kaplan, Jerusalem Sports Medicine Institute, Lerner Sports Center, Hebrew University of Jerusalem, 1 Churchill St., Mount Scopus, Jerusalem, Israel, Tel: 972-2-502-3941; Fax: +972-2-581-2102; E-mail: sportmed@zahav.net.il; www.jsportmed.com

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to a year to achieve normalized gait biomechanics in these patients [1,21]. Early normal gait restoration has shown not only to be safe, but essential to rapidly regain normal muscle function and to significantly lower post-surgical complications, such as knee stiffness [22,23]. As a result, it is accepted that early full weight-bearing should be a primary rehabilitative goal from almost immediately post-ACLR [22,24]. In order to improve weight-bearing deficits following ACLR, it is initially required to ascertain the magnitude of these deficits. This becomes especially challenging when bilaterality exists and there is no healthy limb for weight-bearing comparison. This was the primary purpose of utilizing the Smartstep™ system*. The SmartStep™ pneumatic insole system measures key gait parameters during ambulation. The data are received and then analyzed by the miniature portable microprocessor, which is worn around the ankle. This is subsequently transmitted to a computer system running the SmartStep™ software, which also maintains patient's medical records. The software additionally functions as an assessment of gait analysis, which includes weight-bearing distribution, stance/swing phase and cadence values. The device further contains a biofeedback training application for rehabilitation. The main advantage of this system over other laboratory measuring devices lies in its ability to measure weight-bearing parameters in various functional settings, for example, walking, running and stair negotiation. These above mentioned devices are expensive, with measurement apparatuses that are not commonly portable. Additionally, they are not readily available in clinical and rehabilitation settings and cannot be adapted for usage in popular sporting activities

The aim of this case report was to describe for the first time, the use of a relatively new innovative computerized air-insole auditory biofeedback system as an adjunct in the evaluation and restoration of functional activity (symmetric gait patterns, weight-bearing and biomechanics) in the early stages of rehabilitation following a SBACLR. Clinical recommendations were provided.

*(Smartstep™ System, Andante Medical Devices Ltd, Omer Industrial Park, bld. 8b, Omer 84965, Israel. info@andante.co.il).

Case Report

Patient history

L.L., a seventeen yr. old girl from Cambodia, was referred to our clinic, 3-weeks post-ACLR. She was a very active athlete and had competed in different sports from a young age, including basketball, handball, soccer, and hockey. A year prior to the surgery, she had fallen during a basketball game and had twisted her right knee. She was diagnosed by a local orthopedic surgeon as having sustained a complete

rupture of her right ACL. After a month's course of physical therapy treatment, she returned to full sporting activity. Six months later, while playing hockey, she was pushed, and subsequently twisted her left knee. Following a clinical examination, she was diagnosed with a complete rupture of her ACL, with a suspicion of a complete rupture of her MCL. After the injury, she once again underwent physical therapy rehabilitation; however she was unable to return to sporting activities.

In order to evaluate her functional ability, the Lysholm questionnaire form (LQF) [25], Tegner Activity Level Scale (TALS) [26] and the International Knee Documentation Committee (IKDC) [27] scores were used at different stages of her rehabilitation process. Her pre-surgery results indicated a gross deficit in functional activity (Table 1). It was agreed to perform a SBACLR and an MCL repair in Sweden. The operation was performed using the bone-patella-bone method. The referral report received by the authors indicated that her rehabilitation program started four days post-surgery for a period of three weeks. She was instructed to ambulate as tolerated with the use of Canadian elbow crutches and to wear bilateral knee braces. She performed closed-kinetic chain hamstring and quadriceps strengthening exercises over this period.

Rehabilitation program

When the patient arrived at the Lerner Sports Center, Hebrew University, three weeks post-surgery, she was still ambulating with crutches, as well as wearing bilateral knee braces (Figure 1).



Figure 1: Athlete Walking on Admission.

Knee range of movement								Quadriceps strength (Kg/force)Hand-held Dynamometer- (Jamar®, Sammons Preston, Inc)					
End of week 3				End of week 7				End of week 3		End of week 7			
	Right		left		right		left		right	left		right	left
Extension	0°		0°		0°		0°		11	12		28	25
Flexion	120°		80°		140°		140°						
									Average entire foot % body weight / weight-bearing values				
	Pre-surgery		End of week 3		End of week 7		At one year		End of week 3		End of week 7		
Lysholm score	right	left	right	left	right	left	right	left	right	left	right	left	
	68	50	62	58	88	76	100	100					
IKDC score	50	35	65	50	90	70	101	101	62%	68%	96%	108%	
TALS	2		3		5		10						

Table 1: Measurements During Rehabilitation.

On initial examination, it was difficult to ascertain definite, objective lower-limb atrophy or swelling because of the inability to establish a comparison with the contralateral uninjured side. A summary of her muscle strength tests, range of motion, LQF and TALS and IKDC scores at initial examination are summarized in Table 1.

Her physiotherapy program consisted of three treatment sessions per week, each lasting for 90 minutes, over a period of four weeks. Her initial rehabilitation protocol included individual sessions with either one of the authors and was based upon the accelerated protocol, which has been previously published in the literature [7]. It consisted of lower-limb open and closed chain strengthening exercises, electrical muscle stimulation and neuromuscular sensory training. The program then progressed to simple polymeric and sportmetric-type exercises and perturbation training on uneven surfaces. As an adjunct to this program, starting from the initial treatment, she had six sessions with the SmartStep™ weight-bearing system (Figure 2) which was used both as a weight-bearing monitoring system as well as a biofeedback training mechanism. This was done in order to improve and encourage her weight-bearing until she had achieved equal full weight-bearing bilaterally. She provided informed consent to the use of the Smartstep™ apparatus during her rehabilitation program as well as to her participation in this case study.

In the first evaluation with the Smartstep™ system (during the fourth week of her rehabilitation), she was instructed to walk at a normal pace over a hard surface for a 10 meter distance, while the Smartstep™ system measured her weight-bearing status. The results of this evaluation

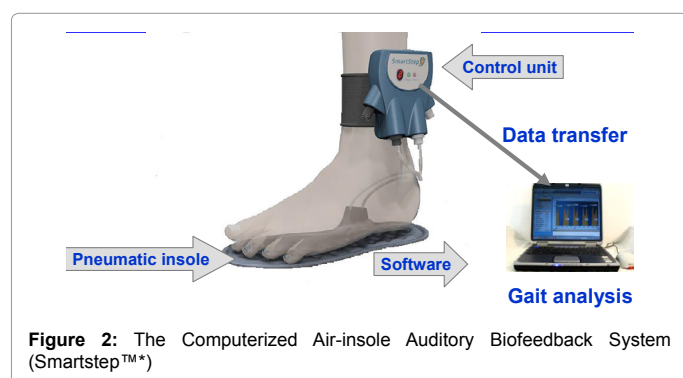


Figure 2: The Computerized Air-insole Auditory Biofeedback System (Smartstep™)

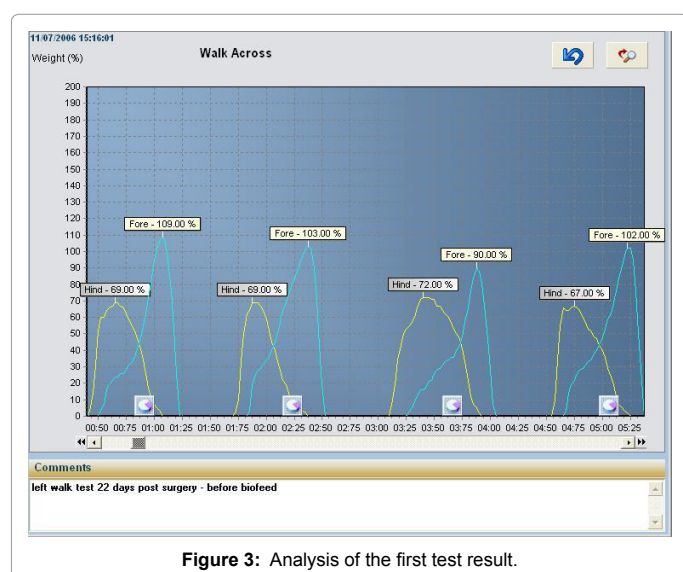


Figure 3: Analysis of the first test result.

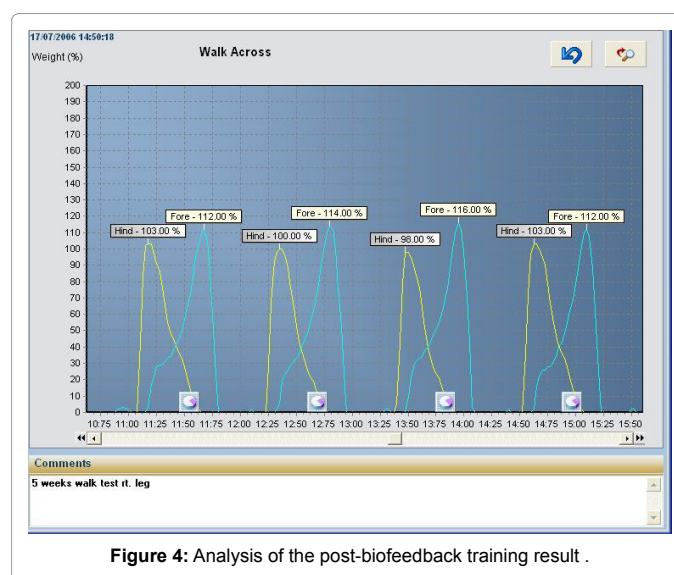


Figure 4: Analysis of the post-biofeedback training result .

(Table 1) showed that her bilateral hind-foot weight-bearing values were significantly reduced (Figure 3). The normal average percentage hind-foot body-weight values in walking have been reported to be 82.33% [28].

Results

After two weeks of rehabilitation in the Lerner Center, L.L. reached full, equal weight-bearing bilaterally (Figure 4). At seven weeks post-surgery, she displayed a marked improvement in her LQS, TALS and IDKC scores. After four weeks of rehabilitation in the Center, she returned to Sweden, where she completed her rehabilitation. She returned for a visit one year later and reported a full and symptom-free return to all previous functional and sporting activities (Table 1).

Discussion

This is the first case study in the literature describing the use of the Smartstep™ system as an adjunct therapy post - ACL reconstruction. The Smartstep™ system indeed provided initial evidence that it was an accurate and objective system, both in terms of its measurement parameters, as well as its biofeedback capability in rehabilitation following SBACLR. It further enabled an accurate comparison to normal weight-bearing values and gait characteristics, without relying on the unaffected limb alone for comparison.

The case study adds somewhat to the limited evidence currently available in the literature, that SBACLR is a safe and clinically effective treatment modality for patients presenting with symptomatic bilateral ACL deficiency. There was a marked functional improvement in the patient's progress over a relatively short time period of seven weeks. The authors were able to take advantage of the profusion of evidence relating to the efficacy of different treatment protocols in the treatment of a unilateral ACLR, and utilized previously described treatment regimes. This rehabilitation strategy when applied to bilateral reconstructions relies on the concept that while one knee is undergoing rehabilitation, the other knee is also being rehabilitated.

Shelbourne [7] has emphasized the importance of regaining symmetrical knee strength and function in achieving early return to function [24]. The rehabilitation program undertaken by the patient in this case study embraced this philosophy. She was able to return to full, unrestricted activity involving cutting and pivoting activities,

where normal and equal strength are required bilaterally. This is in concurrence with the results of studies indicating that there was no observable difference between the recovery time of patients undergoing unilateral surgery and those undergoing bilateral ACL reconstruction [15].

Many surgeons are unwilling to consider SBACLR, as they wish their patients to have an unoperated leg following surgery. This is in order to prevent potential complications during the procedure or during the rehabilitation process thereafter.

There are several challenges that the rehabilitation team faces following a SBACLR. The primary difficulty being the objective evaluation and measurement between the two limbs throughout the rehabilitation process. It remains difficult to obtain an objective comparison pertaining to the swelling, strength and neuromuscular differences between the two legs, as there is no "healthy" contralateral side for comparison. Additionally, there is no paradigm upon which to base the rehabilitation, as it has not been previously reported in the literature.

This is a single case study only, and its conclusions should provide the basis of a future long term prospective study including a much larger cohort of patients who have undergone SBACLR. A randomised control trial may be undertaken comparing the results gained by using the SmartStep system early in rehabilitation vs. a control group. The clinical relevance of a potentially reduced period of rehabilitation by doing the one-stage SBACLR, as well as reduced anesthetic and operating time when compared to staged or non-simultaneous bilateral ACL reconstruction, are important considerations that require further study. It must be noted however, that Jari & Shelbourne [15] have emphasized that severe bilateral quadriceps weakness may be a relative contraindication to bilateral ACL reconstruction.

Conclusions

The Smartstep™ system proved to be a useful objective and accurate adjunct during the rehabilitation process. This study demonstrates that following this relatively uncommon operative procedure, an SBACLR and an MCL repair, it is possible to return an athlete to full, active, functional activities of daily living, together with a high-level of sporting activity. What is evident however is the need for more studies to be conducted in order to further optimize rehabilitation protocols after ACLR in general and in particular, following the SBACLR procedure.

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