Global Journal of
Addiction & Rehabilitation Medicine
ISSN: 2573-2447

Research Article
Volume 7 Issue 3 - October 2023
DOI: 10.19080/GJARM.2023.07.555713

Glob J Addict Rehabil Med

A New Electromagnetic Technology as a Strategy to Help the Recovery of the Anterior Cruciate Ligament Injury in Athletes: A Pilot Study

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Submission: October 06, 2023; **Published:** October 18, 2023

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Abtract

Background: Because of its anatomical location, the knee joint has to sustain enormous forces during exercise and physical activity. One of the most frequent damage affecting ligaments in the lower body is the Anterior Cruciate Ligament (ACL) injury. Treatment may include rest and rehabilitation physical exercises. This study wanted to explore an alternative method for supporting ACL injury recovery using an electromagnetic device for young athletes.

Methods: A total of 10 athletes, 4 females and 6 males, who had undergone ACL surgery for the first time were considered. They ranged from 15 to 22 years.

Results: After two months of follow-up from the experiment starting time, our results showed for every patient an evident muscle tonification in both limbs.

Conclusion: Our data showed that for athletes combining physical exercises with the electro-magnetic technology had led to a significant and positive improvement in muscle tone and strength without discomfort or side effects in patients after ACL surgery. A milder approach gives the athlete a gradual recovery and a variable intervention window based on the patient's characteristics and personal needs. The device we used represents valuable and effective support that could be widely employed in the physiotherapy field.

Keywords: Physiotherapy; FMS (Flat Magnetic Stimulation); Muscle toning, Athletes; Anterior cruciate ligament (ACL) injury; Cryotherapy; Electrostimulation; Heterogeneity; Echography; Homologous limb; Neurological diseases

Introduction

Because of its anatomical location, the knee joint has to sustain enormous forces during exercise and physical activity. Therefore, it is not surprising that 15-30% of sport-related injuries affect this body structure [1]. Confirming this, Swenson et al. [2] carried out a retrospective study in several American high schools describing knee injury rates by sport, accounting for 15.2% of all high school sport-related damages [2]. One of the most important ligaments in the lower body is the Anterior Cruciate Ligament (ACL). This is a key structure in stabilizing the knee joint and connecting the femur to the tibia, so it is crucial for daily life activities and sports [3]. ACL injury is widespread, especially in under-25-years subjects and specifically in sports that involve sudden stops or changes in direction, jumping, and landing (soccer, basketball, football, downhill skiing) [1,4]. The main symptoms reported are pain, swelling, and difficulty moving the joint. Depending on the severity of the ACL injury, treatment may include rest and rehabilitation physical exercises on both legs, electrostimulation, and cryotherapy [5] to help regain strength and stability. Similarly, when the damage is too consistent, and surgery is needed to replace the torn ligament, pre-and post-surgery physiotherapy is crucial for a rapid and effective recovery, as well as all the above-mentioned strategies [6]. Therefore, maximizing muscle mass is the primary strategy in the athletes' population. Even if there are several preventive programs in the physiotherapy routine, the possibility of re-injury is very high, with a second ACL injury rate of 23% in under 25 years athletes who return to sport within two years from the first reconstructive surgery [7,8]. In addition, the risk of injury on the same knee lasts for five years from the first lesion [9].

Although in recent years, the sports sector has raised a solid and challenging need for quick muscular injury recovery, there is substantial heterogeneity in the ACL rehabilitation protocols available in the scientific literature. Criteria for managing the athlete's signs of progress are not standardised as well as the follow-up timings and the requirements that should be met before returning to sport [10]. Indeed, Magnetic Resonance Modelling with electromagnetic technology is the latest advancement in non-invasive muscle toning [11-17]. Magnetic stimulation has been used to effectively treat various medical conditions, such as urogynecological, neuro-psychiatric, and musculoskeletal disorders [18-20]. Furthermore, athletes show different muscle fiber compositions depending on the sport: a marathon runner may have approximately 80% low-twitch red fibers, while this percentage is lower in a sprinter. Thus, choosing personalised and efficient strategies is crucial, especially after surgery. In this scenario, this pilot study wanted to explore an alternative method for supporting ALC injury recovery using an electromagnetic device for young athletes. The technology used is Flat Magnetic Stimulation (FMS), which can make a muscle passively contract without brain involvement.

Materials and Methods

All treatments were performed at Prosperius Lab at Villa Cherubini clinic in Florence between February and April 2022.

Study Population

A total of 10 athletes, 4 females and 6 males, who had undergone ACL surgery for the first time were considered for the treatment. They ranged from 15 to 22 years old with a mean age of 19 years old. General Information, such as the type of sport performed, injury, and date of birth, was collected for every patient. Specific physiotherapy was performed during the whole study period but just the injured limb was treated with electromagnetic technology while the other was considered as a control.

Device technology

The device system is a medical device used primarily for body fat reduction and body remodelling [21] but it has already demonstrated its potential as a muscle-toning tool [22,23]. The patients were treated on the injured limb with the device using the Flat Magnetic Stimulation (FMS) technology, which made the muscles move without brain involvement thanks to up to two pads applied on a specific body area. Right after ACL surgery and for 7-8 weeks ("pre-treatment" step), the patients started a rehabilitation process with physiotherapy, orthopaedic devices and crutches (see Figure 2 for the study timeline). Thus, the study population was considered moderately active with normal muscle tone and the treatment with SCHWARZY started 7-8 weeks after the ACL surgery (still further supported with physiotherapy exercises only). They were treated for 27 sessions (9 weeks, 2 months of follow-up), three times a week. For all the treatments, the Muscle "Shaping 1" protocol was used. It is characterised by the alternation of muscle contraction and resting steps, repeated in series, to avoid lactic acid formation. Moreover, the stimuli are trapezoidal-shaped, and the frequency is adjustable (around 25 Hz).

Physiotherapy protocols

Patients were involved in a dedicated physical activity to make the athlete regain the ability to bend the knee of about 130° after 4-5 weeks from the treatment start (stretching and pull-ups). Moreover, specific exercises were performed to improve proprioceptive ability (balance exercise devices), muscle flexibility, and strength (exercise bike, treadmill, skill mill). All the activities were repeated ten times per session and slowly increased based on the patient's feedback.

Functional Measurements

A monthly medical visit was conducted for every patient for three months. The muscular trophism of the quadriceps was evaluated during every session: the thigh circumference was taken on the standing patient at 6 cm, 12 cm, and 20 cm from the kneecap top, respectively. The mean value of three measurements was reported.

Statistical Analysis

A paired Student's t-test was used to compare the treated and treated legs of every patient Statistical significance is accepted to be $p < 0.05$. Moreover, with the ANOVA test, data groups regarding the differences in the volume of both treated and not treated thighs were compared. In addition, the variability within these data was calculated with the variability between the groups. Statistical interpretations were carried out with the SPSS program version 25.0 (IBM).

Results

The type of injury, sport, and treated limb are specified. Soccer was the most common sport (4/10, 40%), followed by athletics (2/10, 20%), taekwondo (1/10, 10%), jujitsu (1/10, 10%), tennis (1/10, 10%), and rugby (1/10, 10%). In two (2/10, 20%) patients, a medial meniscus injury was present besides the ACL injury, and one patient had damage to both menisci (1/10, 10%). There was no relevant difference between the incidence of ACL injury in the right or left thigh. After two months of follow-up from

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the experiment starting time (see "Before" rows in Table 1), our results showed for every patient an evident muscle tonification in both limbs. Table 1 shows the patient's thigh measurements (averages) at different distances from the kneecap top (6, 12, 20cm), and the difference in thigh circumference values (Δ) between the treated and not treated limbs. Measurements were taken two months after the surgery ("Before" in Table 1), then at three months (1-month Follow Up - FU -) and four months from the surgery (2-months FU). Standard deviation (STDEV) values are also reported. The STDEV ranges are wide because all the patients were considered at the same time. Moreover, we performed a paired Student's t-test comparing values of a single thigh from the same patient at the beginning and at the end of the treatment. Overall, for treated and not treated limbs, a p-value <0.05 was obtained. Whereas, when the Student's t-test is carried out considering treated and not treated limbs at a fixed timepoint, results were not statistically significant ($p>0.05$). When the ANOVA test is performed, only the 20cm measurement results are not statistically significant even if a slight increment is present.

Table 1: Patient's thigh measurements at 6 cm, 12 cm, and 20 cm from the kneecap top at different time points (before the treatment with the device, at 1 month and 2 months of Follow-Up – FU-). All values are an average between all measurements. The "Treat" group refers to the limb that has undergone surgery and is then treated with the device and physical exercises.

	Treat (cm)	Not treat (cm)	Δ treat/not treat	p value T0/2-month FU (treated)	ANOVA Test
			6 cm		
Before	42,60±2,49	43,95±2,08	1,35	6.20E+00	0,03
1-month FU	43,50±2,40	44,3±2,48	0,8		
2-month FU	44,40±2,09	44,95±2,17	0,55		
			12 cm		
Before	48,30±2,65	49,75±3,12	1,45	1.70E-01	0,03
1-month FU	49,15±3,10	50,10±3,10	0,95		
2-month FU	49,80±3,10	50,55±3,10	0,75		
			20 cm		
Before	53,10±3,21	53,70±3,40	0,6	0,000773302	0,36
1-month FU	53,90±3,15	54,35±3,20	0,45		
2-month FU	54,40±2,92	55,20±3,09	0,8		

Figure 1: Image showing a tight bilateral treatment with SCHWARZY. Our experiment used just one pad (on the injured limb) per time. During the session, the patients were lying on the couch in a supine position. Clothes were allowed if tight to the skin.

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A graphical representation of the differences in thigh circumferences in treated and not-treated legs at different time points is reported in Figure 3. Even if the difference was slight, in all cases, it was bigger before the beginning of the treatment with the device combined with physical exercises than the follow-ups. Specifically, considering the treated legs, the mean difference before the treatment and after 2 months of follow-up was 1.80 cm at 6cm from the kneecap, 1.50cm at 12cm, and 1.30cm at 20cm.

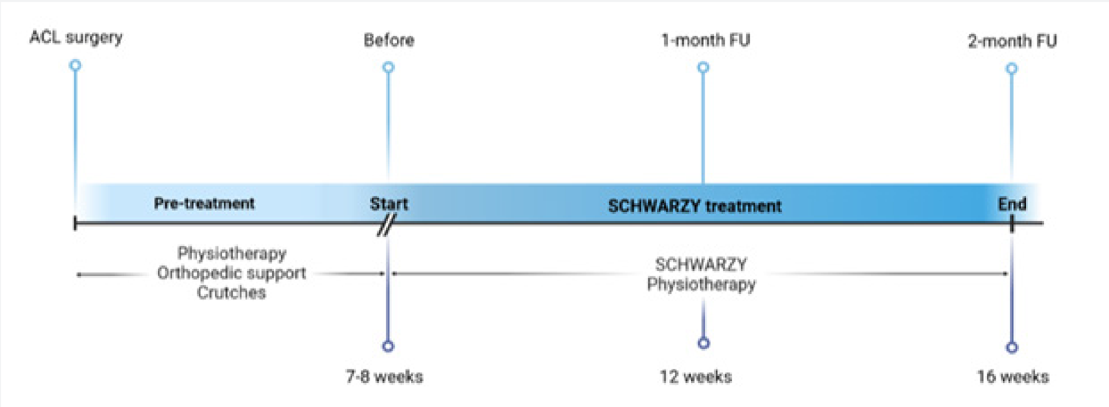

Figure 2: Study timeline. Right after ACL surgery, patients started physiotherapy using orthopaedic supports and crutches. After 7-8 weeks they started the treatment with SCHWARZY and kept carrying out physiotherapy without any support. Patients were followed for two months since the beginning of the treatment. The study ended 16 weeks after the ACL surgery.

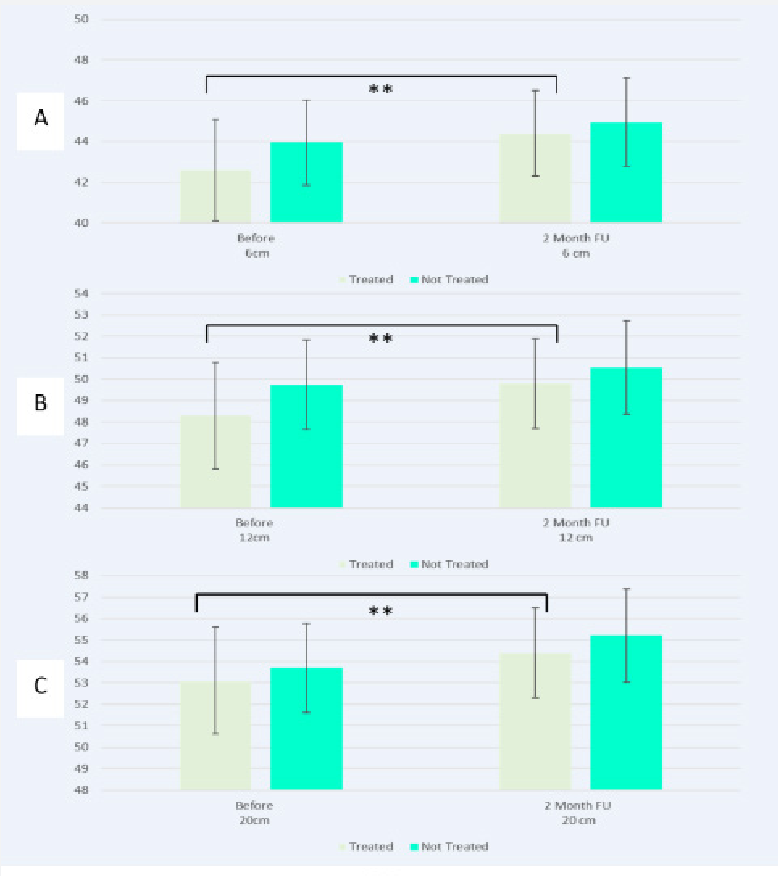

Figure 3: Graphical representation of the differences in thigh circumferences in treated and not treated legs. In pictures A, B, and C the measurements at 6-12-20 cm from the kneecap top respectively are shown. Student's t-test was carried out.

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Discussion

Our data showed that for athletes combining physical exercises with the Flat Magnetic Stimulation technology had led to a significant and positive improvement in muscle tone and strength. Confirming these findings, Leone et al [22] previously reported that with the same technology, it was possible to obtain an increase in muscle thickness ranging from 14% to 23%. Similarly, in our results, there was no statistically significant difference between the treated and not treated thighs but a considerable diversity between measurements of the same limb at the experiment starting point and after two months of follow-up. Data analysis with the ANOVA test proved to be ineffective when measurements at 20cm are considered. Although there is a slight increase, this fact could be due to the anatomical area involved. Indeed, it is the rectus femoris muscle that probably had a minor decrease in muscle trophism after the surgery. Nevertheless, our results showed a general increase in dimensions and circumference in treated limbs suggesting a probable improvement in muscle strength. The diversity between the legs' dimensions can be explained by the lighter protocol used ("Shaping 1") for the experiment. A milder approach gives the athlete a gradual recovery and a variable intervention window based on the patient's characteristics and personal needs. However, low-frequency levels and the "Rest-Hold-Fall" shape of the impulse can be modified if needed. As a matter of fact, having the possibility of a 1-50Hz frequency range and different shapes of impulse (square wave, ladder, sinusoidal, trapezoidal), have opened the device employment to various medical areas. Moreover, it is widely demonstrated that electromagnetic waves can have many applications. For example, there is a chair-shaped device that, thanks to the TOP Flat Magnetic Stimulation (TMS), is now largely used for the treatment of urinary incontinence, persistent vulvar pain and vulvodynia, and other disorders and dysfunctions with remarkable results [24-26]. In conclusion, the use of non-invasive medical strategies represents an incentive for the patient to pursue the treatment and improve their quality of life.

Study Limitations and future perspectives

Our future goal will be to increase the number of patients, including a control group, and employ multiple study device protocols. Specifically, it would be more advisable to have a control group not receiving any treatment with Flat Magnetic stimulation. Indeed, previous studies demonstrated that cross-education can happen. This implies a strength gain in the contralateral limb following a unilateral training program on the homologous limb [27]. Due to this, unilateral training of the unaffected limb has been proposed as a therapeutic approach to help gain strength and skills in patients with acute injuries, immobilisations, or musculoskeletal and unilateral neurological diseases [27,28]. Furthermore, muscular strength and tone need to be thoroughly investigated. For example, it would be interesting to collect qualitative data such as echography or ultrasound [29] exams to assess muscle improvement and evaluate the patient's comfort and satisfaction levels to determine compliance with the treatment. We also hypothesise that an increase in trophism can correlate with a stabilization of the athlete's sports activities and that after ACL reconstruction, it might be important to use therapeutic strategies that decrease the loss of muscle strength through central neural mechanisms. In addition, we think that the innovative technology we propose in this study could be a valuable opportunity to treat fragile population categories such as the elderly and disabled who need to improve and maintain muscle tonicity [30].

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