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Original Article

Clinical effect of combined therapy with capacitive and resistive electric transfer in athletes after anterior cruciate ligament reconstruction

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Abstract:
Anterior Cruciate Ligament (ACL) injuries are one of the most common in athletes. In most cases, it is necessary to interrupt sports activity for a long period of time between 6 to 9 -12 months. It is not uncommon for athletes to be unable to return to the same pre-injury level after such incidents. Therefore, healthcare professionals are challenged to find the most effective and fastest possible approach to rehabilitation. With the advancement of medicine, surgical interventions and are increasingly minimally invasive and gentle. However, rehabilitation is of primary importance for the effective recovery at structural level and functionality of athletes who have suffered similar injuries. The application of Tecar therapy (CRet) has been popularized for the last 2 decades. There are studies that prove the effect in various musculoskeletal traumas and injuries. However, those who prove the clinical effect of the therapy in athletes after ACL injury are still scarce. This motivated us to follow the effect of CRet application in athletes after ACL reconstruction. **Purpose**: The purpose of the present study is to evaluate the clinical effect of CRet therapy as a supplement to the rehabilitation program for athletes after ACL reconstruction. In addition, another aim of the research is to analyze data and determine whether there is a difference in this clinical effect between males and females. **Material and methods**: The study followed the dynamics of pain (VAS), joint swelling (cm), range of movement (goniometry) and flexors and extensors strength (MMT) in 122 athletes (male and female) aged 18-22 years. The contingent was divided in 2 research groups – experimental (N=61) and control (N=61). All patients followed the same rehabilitation protocol with the difference that EG patients received CRet therapy, while CG patients received electrotherapy. **Results**: Data show a significant reduction in pain and swelling and improvement of the range of movement and muscle strength in EG participants compared to the CG (t-test and Mann-Whitney test). Regarding the clinical effect, no difference was found between male and female athletes in EG after administration of combined therapy with Tecar. **Conclusions**: CRet therapy shows better clinical effect, in both men and women, compared to electrotherapy after ACL reconstruction and can be successfully included as an additional tool in the rehabilitation protocol of such patients.
Key Words: **Tecar, knee, injury, surgery, rehabilitation**

Introduction

The anterior cruciate ligament (ACL) plays an important role in the kinematics of the knee joint. It limits anterior translation of the tibia and stabilizes the knee joint. Mechanoreceptors are located in the joint itself, whose task is to maintain the neuromuscular control of the joint (Erickson et al., 2019). ACL tears occur most often in young and active individuals and can have negative long-term physical and psychological effects (Neeraj et al., 2018). The diagnosis is made after a detailed history of the patient, clinical examination and imaging-diagnostic methods.

Epidemiological data indicate that one of the most common injuries in athletes is the ACL injury. Some studies describe which sports have the highest risk of getting this type of injury. Others show differences in incidence between men and women or in specific countries. In general, the prevalence worldwide is high, but only a few countries have official web-based registries that accurately record the number of ACL reconstructions performed (Neeraj, 2018). Official sources indicate that in the United States the frequency of trauma reaches 200,000, with half of them requiring reconstructive surgical treatment (Neeraj et al., 2018).

The consequence of ACL rupture is a disturbance in the biomechanics of the joint, leading to the development of abnormal movement patterns and chronic instability. This in turn leads to loss of function during dynamic tasks and can cause secondary damage to the menisci and cartilage (Kochman et al., 2022). Complete rupture of the connection, especially in young and active sports individuals, requires surgical intervention and its reconstruction. It is important to note that the favorable outcome after reconstruction of the ACL depends to a large extent on the implementation of adequate and timely rehabilitation (De Sousa-De Sousa et al., 2021; Diermer et al., 2020).

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There are several options for ligament grafting such as patellar tendon autograft, ischiocrural tendon autograft, and in recent years, the method of tendon grafting from a donor (cadaver tissue, bank) has been introduced. The success rates of these three types of interventions are similar and successful in 90-95% of cases. In cases where a donor tendon is used, the surgical intervention is less invasive and the rehabilitation process is faster and easier (Basc et al., 2021). After ACL surgery, physiotherapy procedures are of great importance in order to achieve more effective structural and functional restoration of the joint, relieve pain and restore early flexion due to improved mobility of the knee joint (Culvenor et al., 2022).

Standard rehabilitation is often insufficient for patients after ACL reconstruction, so there is a need to improve existing rehabilitation programs, especially in the early postoperative phase. During the past 20 years, capacitive and resistive electric transfer (CRet), also known as Tecar therapy, is described as one of the effective methods for immediate control of pain symptoms, injuries and diseases in the musculoskeletal system. It delivers high-frequency energy to the tissues, penetrating deeply and causing hyperthermia in the painful area - whether it is muscles, joints or superficial tissue layers (Bahdatpour et al., 2022).

Tecar therapy is an endogenous thermotherapy used to generate heating of superficial and deep tissues. Endogenous therapy is defined as treatment that is not localized to the outermost layer of the dermis, but rather to the deeper layers. It is because of this property that Tecar therapy is able to positively influence blood flow by promoting the elimination of catabolites and increasing specific peripheral vasodilation. CRet procedure creates endogenous heat by using induced electrical currents via 448 kHz capacitive/resistive monopolar radio frequency that generate deep tissue warming. The therapy provides two different treatment modes: capacitive (CAP) and resistive (RES) (Szabo et al., 2022).

These regimens usually come with a variety of electrodes made of medical grade stainless steel. According to Tecar's creators, the two treatment regimens elicit different tissue responses depending on the resilience of the treated tissue. When the active electrode is equipped with an insulating ceramic layer, acting as a dielectric medium, (CAP) and the energy transfer generates only heat in the superficial tissue layers, with selective action on soft tissues with low impedance (rich in water), for example, adipose tissue, muscles, cartilage and the lymphatic system (Rodriguqz-Sanz et al., 2020; Marco et al., 2022). If the active electrode has no insulating layer, the (RES) RF energy passes directly through the body in the direction of the inactive electrode generating heat in the deeper more resistant (low water content) tissue layers such as bone, muscle face, capsules and tendons. Studies conducted to date have shown positive results and the beneficial effects of Tecar therapy in many musculoskeletal disorders, including after ACL reconstruction (Rodriguez – Sanz et al., 2020).

The effect of Tecar therapy has been described in the literature for the past two decades. However, studies on the clinical effect in more common injuries and musculoskeletal dysfunctions are few. Some research indicates that CRet Therapy is an excellent therapy that can be incorporated into a rehabilitation program or used alone (Marco, et al., 2022). Other studies prove that Tecar therapy significantly improves endurance, physical function and knee pain, and that this type of therapy could reduce pain, stiffness and functional limitations of the knee joint (Marco et al., 2022).

The purpose of the present study is to measure and evaluate the clinical effect of CRet therapy as a supplement to the rehabilitation program and as another treatment for athletes after ACL reconstruction. To the best of our knowledge, no study has been conducted regarding the differences of the effects of CRet therapy for male and female athletes. In the present study, we will analyze whether such differences exist.

Material & methods

For the present study, we primarily used experimental method, observation, graphic and statistical-mathematical method. The research was conducted in the University Research Sports and Rehabilitation Center “Bachinovo” in the period January 2022 - May 2023. This study was conducted under a project funded by Ministry of Education and Science - scientific research of young scientists and postdoctoral fellows, named "Study of the effect of targeted radiofrequency therapy in musculoskeletal dysfunctions and sports injuries" - КП-06-ПМ-53/1. Informed consent for participation and use of personal data for scientific purposes was obtained from all participants. The study was overseen under the Declaration of Helsinki (2013) and approved by the Ethics Committee. It also met the ethical standards for Sports and Exercise Science Research because the General data protection regulation entered into the appliance on 25 May 2018 (Regulation (EU) 2016/679).

Participants

The study included 122 active athletes, aged 18-22 years, with traumatic ACL injury and subsequent operative reconstruction. The contingent was randomly divided into two study groups as follows: 61 subjects in the experimental group (EG) and 61 for the Control group (CG). There were 28 women and 33 men in the EG, and 33 women and 28 men in the CG. The inclusion criteria were as follow: to be active athletes, between the age of 18 and 22, to have suffered an ACL injury with subsequent reconstructive surgery regardless of the surgical approach, and to have not carried out any other rehabilitation programs or medicine to date. Participants were informed that they would receive a specialized rehabilitation program for recovery after ACL reconstruction, but not that EG would receive CRet therapy and the CG electrotherapy. The study had some limitations such as not all participants playing the same sport, not differentiating the type of surgical intervention and not blinded for therapists.

Procedure

Participants of the EG followed the Tecar recovery program and a specialized rehabilitation program and the subjects of the CG received electrotherapy and the same rehabilitation program after ACL reconstruction. Tecar procedures were applied according to a protocol program for ACL (reconstruction) with a Tecar therapy device "GIMA CR - 200", I-TECH.

The rehabilitation program took place over a period of 6 weeks as follows:

First - second week: 4 procedures per week (total 8) - The first 8 procedures, were performed with only capacitive mode for 20 minutes, with the aim of controlling the pain and reducing the swelling. Capacitive mode acts on the more superficial layers and has a draining effect. From the 1st to the 14th day after surgery, the goals of rehabilitation were to reduce pain and swelling, restore range of movement to 90 degrees of flexion and full extension, and strengthen the thigh muscles (m. Quadriceps femoris).

Third – fourth week: 4 procedures per week (total 8) - We carried out the following 8 procedures according to a protocol program for ACL injury/reconstruction combining Tecar procedure with the possible active movement of the knee joint (static and dynamic). The duration of the Tecar procedure was 30 minutes, of which - 15 minutes capacitive and 15 minutes resistive mode (Fig. 1). From 2nd – 4th weeks after surgery, the goals of rehabilitation were to reduce pain and swelling of the joint, to treat the cicatrix, after removing the sutures, to maintain full extension and to achieve 110 degrees of flexion in the knee joint. It is important to restore the normal arthrokinematics of the knee, to train the patient in correct walking without aids. Specialized exercises for strength, flexibility, coordination and balance were applied (Grueva-Pancheva et al., 2021; Gramatikova et al., 2014). The intensity of the applied exercises gradually increases. The complex includes gradually faster walking, squatting, and going up and down stairs.

Fifth – sixth week: 2 procedures per week (total 4) - according to a protocol program for ACL injury/reconstruction combining Tecar procedure with the possible active movement of the knee joint (static and dynamic). The duration of the Tecar procedure was 30 minutes, of which - 15 minutes capacitive and 15 minutes resistive mode. The goals of rehabilitation in this period were to achieve full range of movement in the joint and restore 80% of muscle strength. Exercises of higher intensity and duration were applied – fitness and running.

Fig. 1. Tecar therapy protocol program after reconstruction of Anterior Cruciate Ligament reconstruction.

The rehabilitation program for patients from both research groups in the last 8-12 weeks ends with maintenance of range of movement, application of sport-specific exercises for strength, flexibility, coordination and balance (Grueva-Pancheva et al., 2021; Gramatikova et al., 2014). Athletes can return to low-intensity sports gradually, but to active sports no earlier than 6 months after surgery.

The patients from both research groups were given a treatment course of 20 procedures with a duration of 40-50 minutes for each.

Test protocol

Anthropometric measurements of the height and body mass of the participants in the study were carried out, and the age indicator was tracked. Regarding such parameters, no statistical differences were observed. This shows the homogeneity of the study contingent and the possibility of comparing them with respect to other indicators. For pain assessment we used the Visual Analogue Pain Scale (VAS), the range of movement for the knee joint was measured using the standard Goniometry method and represented in degrees according to the SFTR method (Gogia et al., 1987). A centimeter was performed through the patella to report edema at the beginning, and also used to account for the presence of muscle hypotrophy of some main muscles and muscle groups during rehabilitation. Manual Muscle Testing (MMT) for flexors and extensors of the knee was performed to compare the muscular strength. VAS is a scale for subjective reporting of the degree of pain. In VAS, the patient himself determines the degree of pain, with 0 meaning no pain, 1-2 – minimal pain, 3-4 – mild pain, 5-6 – moderate pain, 7-8 – severe pain, 9-10 – unbearable (maximum) pain. The therapist monitors the patient's reaction and, taking into account the facial expression, expands the received information. For this purpose, an analogous scale according to Wong Baker (Wong Baker Face Scale) was used to assess pain by facial expression (Delgado et al., 2018). The joint edema reading was followed by centimeter of the knee joint using a standard tape measure. The circumference of the knee through the center of the patella was measured in cm.

The quadriceps has been shown to be one of the most affected muscles in this type of injury. It has been proven that restoring his strength is not an easy task for both the athlete and the therapist. Its rapidly occurring

hypotrophy and slow and difficult recovery are a serious challenge in the rehabilitation of the knee after ACL reconstruction. MMT is a method of determining muscle strength (Cuthbert et al., 2007). The strength of the examined muscle or muscle group is reported in 6 degrees (from 0 to 5), where 0 is the absence of muscle activation, 1 is a slight twitch, degree 2 - performs the movement in full volume, but when gravity is eliminated, degree 3 - performs the movement against gravity and at full volume, grade 4 - performs the movement at full volume against 75% of maximum resistance and grade 5 - performs full volume of movement against maximum resistance. We have measured the strength of flexors and extensors of the affected leg of patients from both study groups.

Data collection and analysis / Statistical analysis

The measurements were done before and after therapeutic course (20 procedures). Statistical analysis included descriptive statistics and inferential statistics element. All anthropometric indices and special test data are presented as means with standard deviations (SD), median, min and max values and coefficients of variation, obtained by descriptive statistics. For comparison of means and medians, the t-Student test was applied, parametric test for unpaired data, Mann – Whitney test and Wilcoxon test, non-parametric test for unpaired data respectively for paired data. To test the hypotheses of the presence of statistically significant differences in the average values of the indicators – circumference of the knee and goniometry for flexion of the knee, the t-test for independent samples was used, since the volume of samples is larger than 30 and the indicators are quantitative signs (interval scale values). For the remaining indicators, the non-parametric Mann-Whitney test was used because they are ranked (ordinal scale values). The significance threshold chosen for p was 0.05. Statistical analysis was performed using the SPSS utility.

Results

The results obtained during the research show that the two groups of examined contingent do not differ statistically in regard to anthropometric parameters. The main characteristics data of the participants are presented on Table 1. No statistically significant differences were found for both groups with respect to height, age and body mass (kg) (t – test and Mann Whitney test). The data presented show that the groups with similar results are assumed to be homogeneous and further differences in the obtained results are due to the difference in the techniques used to treat ACL.

Table 1. Main characteristics of the studied contingent

Contingent		Indicator	Mean	Median	Std. Dev	Min	Max	N
	M		19.55	19.00	1.121	18	22	33
EG	F		19.68	19.50	1.416	18	22	28
	T	Age (years)	19.61	19.00	1.255	18	22	61
	M		19.50	19.50	1.106	18	22	28
CG	F		19.70	19.00	1.380	18	22	33
	T		19.61	19.00	1.255	18	22	61
	M		76.00	76.00	2.092	71	81	33
EG	F		73.96	74.00	1.934	70	80	28
	T	Weight (kg)	75.07	75.00	2.250	70	81	61
	M		75.39	76.00	2.424	71	81	28
CG	F		74.79	75.00	2.088	70	81	33
	T		75.07	75.00	2.250	70	81	61
	M		185.39	186.00	2.633	178	188	33
EG	F		175.89	178.00	3.563	170	180	28
	T	Height (Cm)	181.03	180.00	5.674	170	188	61
	M		181.46	181.50	5.146	170	188	28
CG	F		180.67	180.00	6.142	170	188	33
	T		181.03	180.00	5.674	170	188	61

**M – male; F – female; T- total group*

On the Table 2 is presented the pre-treatment and post-treatment data for pain, swelling, range of movement and muscle strength of flexors and extensors of the knee joint for both EG and CG patients. The first step was to analyze data pre-treatment for both groups. There were no statistically significant differences between two groups at the beginning of the study (Mann-Whitney). This proves the homogeneity of the groups at the beginning of the study and proves that the differences obtained at the end of the research period are due to the applied therapy. The second step was to analyze the difference pre and post treatment for subjects of the EG and CG. We observe significant differences compered to pre-treatment data for patients of the EG in regard to all obtained values (Wilcoxon test, $p<0.05$). We also analyze the post-treatment results comparing EG to the CG subjects. For obtained data of knee circumference (cm) and flexion degree of the knee we used T-Student test, $p<0.05$. We observed statistically significant differences, compared to the CG, between the averages after the treatment period respectively $p=0.001$ for knee circumference $p=0,005$ and for knee flexion degrees. For the rest of the parameters we applied Mann-Whitney test because the obtained data are ordinal scale values. We observed statistically significant differences after six-weeks of treatment for VAS scale values ($p=0,001$), MMT of the knee flexors ($p=0.001$), MMT of the knee extensors ($p=0.001$) and degrees of the knee extension ($p=0.001$) compared to the patients of the CG.

Table 2. Dynamic of the results for subjects of EG and CG before and after treatment

	Group	*N*	*Mean*	*Std. Deviation*	*Std. Mean*	*Error*
Knee circumference (cm) – pre	CG	61	38,664	1,1645	0,1491	
	EG	61	38,703	0,8252	0,1057	
Knee circumference (cm) - post	CG	61	37,934	1,1161	0,1429	
	EG	61	36,749#≠	0,7275	0,0931	
Visual Analogue Scale (VAS - points) - pre	CG	61	7,836	0,8599	0,1101	
	EG	61	8,000	0,7071	0,0905	
Visual Analogue Scale (VAS - points) - post	CG	61	5,918	0,8020	0,1027	
	EG	61	3,508*≠	0,6487	0,0831	
Manual Muscle Testing (MMT) – knee flexors - pre	CG	61	3,639	0,4842	0,0620	
	EG	61	3,557	0,5008	0,0641	
Manual Muscle Testing (MMT) – knee flexors - post	CG	60	4,483	0,5039	0,0651	
	EG	61	4,820*≠	0,3877	0,0496	
Manual Muscle Testing (MMT) – knee extensors - pre	CG	61	3,541	0,5025	0,0643	
	EG	61	3,705	0,4599	0,0589	
Manual Muscle Testing (MMT) – knee extensors - post	CG	61	4,361	0,4842	0,0620	
	EG	61	4,902*≠	0,3003	0,0384	
Goniometry (degrees) – knee flexion - pre	CG	61	107,705	7,9882	1,0228	
	EG	61	106,803	8,9458	1,1454	
Goniometry (degrees) – knee flexion - post	CG	61	116,393	5,7830	0,7404	
	EG	61	128,279#≠	3,9671	0,5079	
Goniometry (degrees) – knee extension – pre	CG	61	-5,574	6,1304	0,7849	
	EG	61	-5,164*	5,6985	0,7296	
Goniometry (degrees) – knee extension - post	CG	61	-2,623	3,7201	0,4763	
	EG	61	-0,246*≠	1,0902	0,1396	

*Statistically significant difference ($p < 0.05$) as compared to control group (Mann Whitney test); #Statistically significant difference ($p < 0.05$) as compared to control group (t-Student test); ≠ Statistically significant difference ($p < 0.05$) as compared to pre-treatment (Wilcoxon test)

The last step was to compare the results obtained between men and women of the EG after the applied therapy. It was interesting for us to analyze whether there were any gender differences regarding to the clinical effect of CRet therapy. Data for male and female subjects of the EG group after treatment is presented on Table 3. We observed no statistically significant differences between man and women of the group after six-weeks of treatment (Mann-Whitney test).

Table 3. Dynamic of the results post-treatment for male and female subjects of the EG group

Experimental group (post treatment)			
Test		***Male***	***Female***
Knee circumference (cm)	*Mean*	36.78	36.71
	Median	37.00	37.00
	St. Dev.	0.78	0.67
	Min.	36.00	35.00
	Max.	39.20	38.00
Visual Analogue Scale (VAS - points)	*Mean*	3.52	3.50
	Median	3.00	3.00
	St. Dev.	0.67	0.64
	Min.	2.00	3.00
	Max.	5.00	5.00
Manual Muscle Testing (MMT) – knee flexors	*Mean*	*4.79*	*4.86*
	Median	*5.00*	*5.00*
	St. Dev.	*0.42*	*0.36*
	Min.	*4.00*	*4.00*
	Max.	*5.00*	*5.00*
Manual Muscle Testing (MMT) – knee extensors	*Mean*	*4.91*	*4.89*
	Median	*5.00*	*5.00*
	St. Dev.	*0.29*	*0.32*
	Min.	*4.00*	*4.00*
	Max.	*5.00*	*5.00*
Goniometry (degrees) – knee flexion	*Mean*	*120.0*	*127.5*
	Median	*130.0*	*127.5*
	St. Dev.	*2.73*	*5.00*
	Min.	*120.0*	*120.0*
	Max.	*135.0*	*135.0*
Goniometry (degrees) – knee extension	*Mean*	*0.00*	*-0.54*
	Median	*0.00*	*0.00*
	St. Dev.	*0.00*	*1.58*
	Min.	*0.00*	*-5.00*
	Max.	*0.00*	*0.00*
	N	*33*	*28*

*Statistically significant difference ($p < 0.05$) comparing male to female (Mann Whitney test);

A comparative analysis of patients of the two study groups was performed. The results obtained before and after therapy in the EG and CG subjects were compared (Wilcoxon test). On the other hand, the post-therapy data of the patients of the two groups were compared (t-test and Mann-Whitney U-test). In the EG patients, an analysis of data obtained at the end of the study period was performed between men and women with the aim to

analyze if there were any differences regarding the effect of CRet therapy between men and women (Mann-Whitney U-test). We observe no statistical difference between results of the men and women of the EG after six-weeks treatment.

Discussion

Our study aimed to follow the clinical effect of CRet therapy in athletes after trauma and subsequent ACL reconstruction. We believe that maximally rapid recovery at the structural level leads to full functional recovery of the injured knee joint. Adequate rehabilitation program after ACL reconstruction is of utmost importance for complete tissue regeneration (Roy et al., 2019; Rusanov et al., 2018). Knee injuries in athletes are one of the most common, with rupture of the ACL being among the first reasons for temporary cessation of sports activity. Rehabilitation is often based on protocolized, time-related programs after surgery (Kostrub et al., 2020; Roy et al., 2019). In most cases, athletes return to training after 4 to 9-12 months of rehabilitation (Rodriguqz-Sanz et al., 2020). Physiotherapists and other medical professionals use CRet therapy with the unique goal of symptom relief, without however taking into account the biochemical and physiological aspects, which to date are still under-researched in the medical scientific community. In many cases, the restoration of the joint is looked at globally, omitting the detailed regeneration of the individual structures and ensuring correct arthrokinematics of the joint. Many athletes cite persistent pain, stiffness, intra-articular swelling, limited range of movement, and muscle weakness as reasons for not being able to return to the same level of training as before the injury.

Previous studies have shown that increasing endogenous heat (CRet) leads to vasodilatation and greater blood saturation in the treated area, while drainage of excess fluid and increased cell proliferation is due to the passage of electrical transfer through the structures. Rodriguez-Sanz et al., 2020, do an interesting study on the effects of CRet on temperature and current in depth structures of the knee joint in cadavers. In conclusion, they report that low-intensity treatment demonstrated minimal capsular and intracapsular thermal effects, but electrical transfer drained interstitial fluid and stimulated cell regeneration. These low-intensity CRet protocols may be indicated for the treatment of inflammatory pathologies where temperature elevation is not of interest. In our study, at the beginning of the rehabilitation program, in the acute postoperative period, we also applied only capacitive electric transfer mode in order to drain and reduce pain symptoms.

High power treatment achieved a greater increase in capsular and intra-articular temperature. It may be indicated for the treatment of chronic pathologies where an increase in deep temperature is desirable to generate viscoelastic changes in deep structures (Rodriguez – Sanz et al., 2020). For example, Coccetta et al. report improvement in knee osteoarthritis patients after a 2-week course of Tecar treatment in terms of pain (VAS) and the Western Ontario and McMaster University Osteoarthritis Index (WOMAC). These results are retained in a relatively long-term period - 3 months after the treatment (Coccetta et al., 2019).

The present study is aimed at the clinical effect of CRet therapy and the maximum functional recovery of athletes and their return to the pre-injury level in the shortest possible period. For this purpose, we used the visual analogue pain scale, we measured the swelling in the joint, range of movement and muscle strength. CRet therapy is increasingly used in rehabilitation and sports medicine to treat various structures in the musculoskeletal system – muscles, tendons, bones, capsule and ligaments. Based on the obtained results in our study, we observe a rapid reduction of swelling in the joint. In addition, data from the VAS pain scale showed that it was also reduced to a greater extent in patients treated with CRet therapy. The obtained results show statistically significant differences between EG patients (comparing pre and post-treatment – Wilcoxon match pair test). On the other hand the post-treatment results of the EG patients were compared to CG and also are better for the participants of the EG (Mann-Whitney test). The first processes that occur in the human body as a normal physiological and protective reaction after a trauma is the increase of the interstitial fluid rich in specialized cells having an important role in the healing of the injured structures (Marco et al., 2022). CRet therapy has been proven to support this process by increasing blood supply to the area and enhancing the proliferative phase (Rodriguez-Sanz et al., 2020). This was also confirmed at the patients of our study. Swelling and pain were significantly reduced in patients treated with CRet compared to CG patients. The capacitive mode of CRet therapy, allows treatment of the patients even in the most acute phase of rehabilitation because has a strong draining effect and does not cause deep heating of the structures. The reduction of pain and swelling, in turn, and the acceleration of healing physiological processes lead to the possibility of earlier mobilization of the joint.As in our study Szabo et al., 2020, reported improvements according to the pain measurement scale after treatment with CRet therapy compared to the beginning of treatment. Following the research analyzed in the literature, the results showed the beneficial effects of Tecar therapy in many musculoskeletal disorders, as in our case, regarding the revision of ACL. Similar to our research Szabo et al., 2020, demonstrated that CRet therapy is an excellent adjuvant therapy and could be incorporated into rehabilitation program or use isolated (Szabo et al., 2020). Besides the intergroup comparison of the results, it was interesting for us to follow whether there is a difference in the clinical effect of CRet between men and women in EG. No statistical differences were observed between the results obtained in the tests after carrying out the Tecar procedures in men and women in terms of pain. Data obtained of VAS scale are reduced practically to the same extent in both genders of patients.

On the other hand, reducing pain allows better joint mobility. Early mobilization of the joint ensures greater range of movement and prevents a number of complications that may occur as a result of immobilization.

After trauma and subsequent surgical intervention, a period of immobilization is required, which can lead to secondary complications such as muscle or intra-articular contractures. Contractures of the posterior joint capsule are particularly common due to the anatomical features and the increase in type I collagen levels already after the first week of immobilization (Rodriguez-Sanz et al., 2020). Studies prove that increasing the temperature in the structures and the passage of current (electromagnetic waves) through them leads to changes such as increased deep and superficial blood circulation, vasodilatation, increased temperature, elimination of excess fluid and increased cell proliferation. Data obtained in relation to the range of movement of the knee joint in our study also show the achievement of a significantly better degrees for the EG patients compared to those in CG after treatment (Mann-Whitney test). Also Szabo et al., 2020 in their study report no statistical differences in relation to knee flexion after 2 weeks of treatment. However, the authors of the research followed patients for 4 and 6 weeks of Tecar therapy and observe significant increase of the degrees of flexion compared to the CG patients.

The analysis of data in regard of knee goniometry (flexion and extension) obtained between men and women in EG show no statistical differences between the results after carrying out the Tecar procedures in men and women. The reduction of muscle strength of the affected limb and its recovery is also a challenge faced by therapists and athletes. The large muscle groups around the knee joint act as its active stabilizers, and their recovery to pre-injury levels is extremely important. CRet therapy is not directly related to the recovery of muscle strength. The specialized exercises included in the rehabilitation protocol and their adequate application lead to an increase in muscle strength in the final stage of the rehabilitation program. From our observations and the obtained data, however, better recovery of knee flexors and extensors was observed in EG patients. We believe that better muscle strength achieved in EG patients is due to the indirect effect of CRet therapy and the faster reduction of pain and swelling, as well as the earlier recovery of joint mobility. The earlier mobilization of the joint and the absence of pain allow more effective application of the specialized complex of exercises and, accordingly, the achievement of greater muscle strength. On the other hand, the earlier, the specialized exercises are applied, the smaller will be the muscle hypotrophy that must be overcome.

Another factor that, according to us and other authors, can affect the increase in muscle strength is the improved blood supply to the structures (including muscle fibers, fascia) which would also lead to their more efficient recovery and functioning. Clijsen et al., 2020 in their pilot feasibility study on healthy subjects, treating the effect of Tecar therapy on microcirculation and intramuscular blood flow (intramuscular blood flow % before and after treatment: placebo 0.05 – 1.1, capacitive – 0.09 – 1.09, resistive 2.06 – 3.3). Following the research, Tecar therapy applied to the subjects, both capacitive and resistive, induced major changes compared to the placebo effect, applied to another group of subjects (skin temperature (degrees): placebo: -2.3 – 1.5, capacitive 0,9 – 1.3, resistive 2.8 – 2). Another study conducted by Coccetta et al., 2019 in which diathermy was reported to significantly improve knee endurance, pain, and function. Furthermore, at their follow-up study, they reported a strong reduction in joint pain and stiffness and less functional deficit after capacitive and resistive electric transfer procedures. The analysis of the results between men and women is interesting here due to anatomical and physiological differences between the two genders. Regarding muscle strength, again no statistically significant differences were observed between the two genders of patients in EG. According to us and other authors, the recovery of muscle strength rather depends on the condition of the muscles before the trauma and the surgical intervention. One of the limitations of our study is that the patients in the two groups underwent a different type of surgical intervention. Of course, during the implementation of the rehabilitation program, we took into account these peculiarities, but the CRet procedures were applied equally to everyone. An object of future studies may be to follow up the effect of CRet in different types of surgical ACL reconstruction.

Conclusions:

The study had some limitations regarding the different type of surgical intervention the patients received. It was also not blinded to the therapists. Although, the contingent was form of athletes in different sports, groups were homogeneous in regard to age and anthropometric characteristics. Subjects were randomly divided in CG and EG and all had strictly completed the therapeutic course and the tests before and after therapy. Obtained data shows reliable differences in favor of the CRet patients in terms of pain, edema, and range of movement and muscle strength. No differences were observed for data obtained from the tests after CRet procedures between men and women in EG. In conclusion, the patients who benefited from a personalized recovery program, combined with Tecar, performed both statically and dynamically, reached optimal results faster than patients who received electrotherapy. Based on the results obtained, we could say that Tecar therapy could be an effective supplement to the rehabilitation protocol or used isolated for patients after ACL reconstruction.

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