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Original Article

Examining the relationship between pain intensity, functional disability and range of movement using TECAR therapy in athletes after anterior cruciate ligament reconstruction

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Abstract:
Capacitive and resistive electric transfer (TECAR) has emerged as a pain-free and non-invasive treatment modality, gaining popularity over the last two decades for addressing various acute and chronic painful conditions. Athletes often encounter anterior cruciate ligament (ACL) injuries. While successful reconstruction is achieved in 90% - 95% of cases, comprehensive rehabilitation is crucial for maximizing recovery and restoring athletes to their pre-injury levels. **Aim**: The study aimed to investigate the direct relationship between pain intensity, knee joint range of movement and functional disability of the lower limb using TECAR therapy in athletes after ACL reconstruction. **Materials and methods**: This cross-sectional study was conduced as a part of a randomized controlled trial involving 122 athletes (both male and female). Following a detailed analysis and comparison of the experimental group (EG, n = 61) and the control group (CG, n = 61), we focused on further examining the results of the EG patients and on determining whether there was any relationship between the measured variables and the functional recovery of the joint. EG subjects received TECAR therapy as a supplement to the rehabilitation program for ACL injury and subsequent surgery. The study monitored pain dynamics (Visual Analogue Scale - VAS), joint edema (in centimeters), range of movement (goniometry), flexor and extensor strength (Manual Muscle Testing - MMT) and Lower Extremity Functional Scale (LEFS). Assessment were conducted before and after the therapeutic course (comprising 20 procedures lasting 40 – 50 min each). The data were analyzed using SPSS version 26.0. **Results**: The Spearman's rho coefficient results for VAS, MMT, range of movement and LEFS varied. The strength of correlation between variables was generally weak but statistically significant ($p < 0.05$, 95% CI; 2-tailed) except for VAS and knee range of movement (ROM) of flexion ($p > 0.05$, 95% CI). **Conclusions**: Intragroup analysis revealed statistically significant differences compared to pretreatment in terms of pain, knee-ROM, muscular strength and functional disability (Wilcoxon test $p < 0.05$, 95% CI). For athletes after ACL reconstruction, TECAR therapy, when used in conjunction with conventional physical therapy, demonstrated a weak correlation between knee-ROM, LEFS and muscular strength.
Key Words*:* **Visual analogue scale (VAS), Lower Extremity Functional Scale (LEFS), range of movement, CRet therapy, knee**

Introduction

Although there are a number of rehabilitation practices that have repeatedly proven their effectiveness, the percentage of athletes who have returned to sports activity after an Anterior cruciate ligament (ACL) injury and reconstruction is not what is expected in practice. Some studies report that about 80% of athletes return to some kind of sports activity after surgery. However, turn-to-sport rates based on sport level, 65% of them do not reach the level of training they had before the injury. Only 55% of all reach pre-injury sports level (Burland et al., 2019).

ACL injury is one of the most common in sports practice. Statistics indicate that approximately 120,000 ACL reconstruction surgeries are performed annually in the United States. Regardless of whether treatment is conservative or operative, physical rehabilitation plays a critical role in athlete's recovery and return to sport. In scientific and medical circles, over the years, various rehabilitation protocols after ACL reconstruction have been discussed. This protocols vary widely with some small consensus among different specialists (Jenkins et al., 2022). In recent decades, however, a number of additional factors have been taken into account that influence the outcome of the rehabilitation process. In addition to physiological factors, psychosocial, personal factors, the environment and specific activity of the patient are not to be underestimated (Burland et al., 2019). Therefore, in

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recent years, the focus of rehabilitation has shifted from conservative, standardized and prolonged protocols to more effective, faster and individualized programs that vary in duration and modalities based on specific patient findings and preferences (Jenkins et al., 2022).

It is only recently that attention has been paid to the psychological factor as important for return to sport in athletes after ACL injury. In a large percentage of cases, the fear of re-injury, kinesiophobia, reduced motivation and a sense of uncertainty are the reasons why the athlete does not return to the sport he practiced at the same level as before the injury (Burland et al., 2019). Some of the most significant factors and conditions for the successful recovery and return to sports of the injured athlete are the correct assessment and diagnosis, informed decision for surgical intervention, preoperative preparation and rehabilitation program aimed at the patient and his specific and personal needs (Brenlee et al., 2022). Other critical factors for the successful recovery and low risk of re-injury of athletes are the time to return to sports activity and the inclusion in the rehabilitation program of specific activities related to the specific sport practiced, as well as, secondary prevention programs (Czuppon et al., 2014).

Regarding the time to return to sports activity, experts have different opinions. The period can vary from a minimum of 6 months to an average of 9 to 12 months. There is scientific evidence, however, that full physiological recovery of the ligament (neoligamentization process) takes 24 months. Only after this period the risks of re-injury is lower (Brenlee et al., 2022). For example, Grindem et al., 2016 reported that the risk of re-injury increases 7 times in athletes who return to sports earlier than 9 months after trauma (Grindem et al., 2016).

Of course, the time to return to sports depends on the type of sport practiced, because some sports carry a greater risk of this type of injury. Undoubtedly, however, 24 months is a too long period for recovery and interruption of sports activity. This is the reason why specialists are looking for ways to maximize quick and effective recovery with minimal risk of re-injury and secondary complications (Jenkins et al., 2022).

Based on the information obtained from the existing literature sources, we believe that a good and reliable rehabilitation program aimed at the needs of the athlete and leading to quick results can significantly reduce the psychological factor as an additional complication. Rehabilitation usually begins even before the operative intervention, as a preparation, and continues immediately afterwards, even in the earliest post-operative period. The inclusion of specialized methods and means that can affect pain and edema could allow early mobilization of the joint. This is the key to preventing unwanted side effects such as delaying the time to return to sports activity.

The effect of TECAR therapy has been described in the literature for the past two decades. 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). The beneficial effect of TECAR therapy are mostly used in physical therapy, rehabilitation and pain management like bruises and sprains, post-surgery rehabilitation and sports traumas. 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).

TECAR therapy uses high-frequency currents for the bio-stimulation of tissue with different resistivity. 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).

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 such as, 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 tissue layers with higher impedance 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).

According to new disability models, the presence of pathology is associated with pain and impaired function. However, pain is not always directly related to impairment, and not every injury leads to impaired function and disability. Successful treatment of a disability must be target-oriented, individualized and based on a proper and detailed examination of the patient. Effective assessment and management of ACL injury requires a good knowledge of the relationship between pain, limitations, and impaired function (Ahmed et al., 2022).

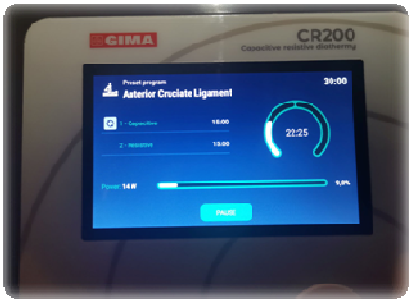
Only a few studies have investigated the direct relationship between pain intensity, impairment and disability. Additionally, this studies show some inconsistencies in the level of correlation between pain, impaired function, and limitation. The purpose of our study is to investigate if exist some correlation or dependencies between intensity of pain, range of motion (ROM), functional disability and muscle strength of the knee joint after application of TECAR therapy in athletes with ACL reconstruction. Our hypothesis is that if any dependence is established between the main limiting factors at the physiological level, they could influence each other and this would lead to better treatment results.

Material & methods

The research method was primarily experimental, observation method, the graphic method and the statistical-mathematical method. The study was conducted as a part of a randomized controlled trial at the University Research Sports and Rehabilitation Center "Bachinovo" in the period January 2022 - May 2023(Avramova et al., 2023). The study is part of 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 61 active athletes, aged 18-22 years, with traumatic ACL injury and subsequent operative reconstruction. There were 28 women (45,9%) and 33 men (54,1%) in the group. The inclusion criteria were to be active athletes, between the ages 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 drug therapy to date. Participants were informed that they would receive a specialized rehabilitation program for recovery after ACL reconstruction combined with TECAR therapy. The study had some limitations such as not all participants playing the same sport, not differentiating according to mode of injury, not differentiating the type of surgical intervention and not blinded for therapists.



Procedure

Participants followed the TECAR recovery program and a specialized rehabilitation program for ACL injury and reconstruction. TECAR procedures were applied according to a protocol program for ACL (reconstruction) with a TECAR therapy device "GIMA CR - 200", I-TECH (Fig.1).
Figure1. TECAR therapy device – "GIMA CR – 200", I-TECH

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

First - second week: Four 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 edema. 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 are to reduce pain and edema, restore knee-ROM to 90 degrees of flexion and full extension, and strengthen the thigh muscles (m. Quadriceps femoris).

Third – fourth week: Four 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. From 2nd – 4th weeks after surgery, the goals of rehabilitation are to reduce pain and edema in 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 artokinematics of the knee, to train the patient in correct walking without aids. Specialized exercises for strength, flexibility, coordination and balance are 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: Two 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 are to achieve full ROM in the joint and restore 80% of muscle strength. Exercises of higher intensity and duration are applied - fitness, running.

The rehabilitation program for patients from both research groups in the last 8-12 weeks ends with maintenance of ROM 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 of the research group 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, and 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 measure and 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) is 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 is 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 all patients.

To assess the functional status of the affected lower limb, we applied the Lower Extremity Functional Scale (EFES). The LEFS is intended to assess functional status in patients with disability of the lower extremity. The patient responds to questions that help determine the degree of difficulty the patient experiences with 20 everyday activities. Each of the activities is evaluated in 5 degrees as follows: 0 - extremely difficult, up to impossible, 1 - with great difficulty, 2 - with moderate difficulty, 3 - with little difficulty, 4 - without any difficulty. All results are summed and divided by the maximum number of points (%). The maximum score is 80 points or 100%, and the minimum score is 0 points (Binkley et al., 1999; Dingemans et al., 2017).

The measurements were done before and after therapeutic course (20 procedures).

Data collection and analysis / Statistical analysis

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. The statistical analyses were performed using SPSS version 26.0. The Wilcoxon signed test for intra-group analysis was used as a test of significance, and a two-tailed *P* value of 0.05 (95% CI**)** was calculated to either accept or reject the null hypothesis. Spearman's correlation coefficient is used to determine if some dependencies exist between pain intensity (VAS), Knee-ROM, functional disability (LEFS) and muscular strength (MMT).

Results

The main anthropometric data of the patients of the EG are represented on Table 1. The mean age of the total group was 19.61 ± 1.25 years, mean weight 75.07 ± 2.25 kg and mean height 181.03 ± 5.67 cm.

Table 1. Main characteristics of the studied contingent

Contingent	***Indicator***	***Mean***	***Median***	***Std. Dev***	***Min***	***Max***	***N***
EG	Age (years)	19.61	19.00	1.255	18	22	61
	Weight (kg)	75.07	75.00	2.250	70	81	61
	Height (cm)	181.03	180.00	5.674	170	188	61

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

Table 2. presents the results of the pre - treatment and post -treatment tests for pain, edema, range of movement and muscle strength of flexors and extensors of the knee joint of EG.

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

EG (n=61)	*Mean*	*Std. Deviation*	*Std. Error Mean*	*Min*	*Max*	*Coef. of Variation (%)*
Knee edema (cm) – pre	38,703	0,8252	0,1057	37.00	42.50	2.13
Knee edema (cm) – post	36,749*	0,7275	0,0931	35.00	39.00	1.98
VAS scale – pre	8,000	0,7071	0,0905	6.00	9.00	12.56
VAS scale – post	3,508*	0,6487	0,0831	2.00	5.00	28.82
MMT (flexors) – pre	3,557	0,5008	0,0641	3.00	4.00	14.08
MMT (flexors) – post	4,820*	0,3877	0,0496	4.00	5.00	8.04
MMT (extensors) – pre	3,705	0,4599	0,0589	3.00	4.00	12.41
MMT (extensors) – post	4,902*	0,3003	0,0384	4.00	5.00	6.13
Flexion (degrees) – pre	106,803	8,9458	1,1454	90.00	120.00	8.38
Flexion (degrees) – post	128,279*	3,9671	0,5079	120.00	135.00	3.09
Extension (degrees) – pre	-5,164	5,6985	0,7296	-15.00	0.00	28.66
Extension (degrees) – post	-0,246*	1,0902	0,1396	-5.00	0.00	27.82
LEFS (%) – pre	19,86	4,065	0,5205	13.80	28.70	20.47
LEFS (%) – post	69,59*	2.688	0,3442	65.00	76.30	3.86

*Statistically significant difference ($p < 0.05$) as compared to pre-treatment (Wilcoxon test $p=0.0001$).
LEFS – Lower Extremity Functional Scale; VAS – Visual Analogue Scale

The intragroup results comparing the values pre and post treatment of the studied contingent shows statistically significant differences in regard to pain intensity, muscular strength, range of movement of the knee joint, joint edema and Lower Extremity Functional Scale ($p<0.05$, Wilcoxon matched pairs test).

Spearman's rank correlation coefficient was used to examine the existence of statistically significant dependencies between the results of the study (Table 3). There is no such golden rule to define a strong versus a moderate versus a weak relationship. However, due to the specificity of our variables we used in this study some general guidelines for health science studies.

Table 3. Correlation analysis between pain intensity, functional disability, ROM and muscle strength
Correlation Analysis

Spearman's rho		VAS	MMT extensors	MMT flexors	Degrees flexion	Degrees extension	LEFS
VAS	Correlation Coefficient	1.000	0.023	-0.060	0.083	0.060	0.004
	Sig. (2-tailed)		0.860	0.648	0.524	0.644	0.977
MMT extensors	Correlation Coefficient	0.023	1.000	0.131	0.126	0.288*	-0.121
	Sig. (2-tailed)	0.860		0.313	0.332	0.025	0.352
MMT flexors	Correlation Coefficient	-0.060	0.131	1.000	0.188	-0.075	0.259*
	Sig. (2-tailed)	0.648	0.313		0.148	0.565	0.044
Degrees flexion	Correlation Coefficient	0.083	0.126	0.188	1.000	0.010	-0.126
	Sig. (2-tailed)	0.524	0.332	0.148		0.942	0.332
Degrees extension	Correlation Coefficient	0.060	0.288*	-0.075	0.010	1.000	0.196
	Sig. (2-tailed)	0.644	0.025	0.565	0.942		0.130
LEFS	Correlation Coefficient	0.004	-0.121	0.259*	-0.126	0.196	1.000
	Sig. (2-tailed)	0.977	0.352	0.044	0.332	0.130	
N		61	61	61	61	61	61

*Correlation is significant at the 0.05 level (2-tailed) (Spearmen's rho)
VAS – Visual Analogue Scale; LEFS – Lower Extremity Functional Scale

Discussion:

In the current study, a correlation analysis was done among pain intensity, functional disability, knee – ROM and muscular strength of the knee flexors and extensors using TECAR therapy combined with conventional physical therapy in athletes with ACL reconstruction. This study found remarkable changes between the results obtained before and after treatment of the rehabilitation program. A similar mean age of 19.61±1.25 years, similar weight of 75.07±2.25 kg and similar height of 181.03±5.67 cm was found for the study participants (Table 1). This type of injury is extremely common and especially among young active athletes. Our study included young athletes actively practicing various types of sports with a high risk of a similar type of injury. The percentage ratio of women to men in the group was almost equal, 45.9% women and 54.1% men. A number of studies prove that the incidence of ACL trauma is about 1.7 times greater in women compared to men (Montalvo et al., 2018). The higher percentage of men in the present research contingent is probably because a large number of them are football players. The significant changes was found in pain intensity, knee-ROM, disability levels and muscular strength.

The pain intensity was reduced from high to moderate and low level (VAS) with statistically significant differences compared to pre-treatment ($p=0.0001$). Many clinical studies prove the positive effect of TECAR therapy in regard to the pain. The mechanisms for achieving analgesia in physical therapy are known and proven. In manual therapy, this effect is achieved by direct mechanical stimuli of the sensory receptors, which block the information originating from the nocireceptors and increase local blood circulation. With this type of therapy, heat is also produced, but it is limited to only the most superficial layers. In a study by Kasimis et al. 2023 and our previous studies reported that the high-frequency current emitted by a TECAR device produces intense heat effect on different tissue levels (muscles, tendons, cartilage, joints and bones). In all of them it is proven that the generation of this deep heat by radio frequency radiation significantly increase cellular metabolism and provide an intense analgesic and healing effect an action that results in a reduction in recovery time (Kasimis et al., 2023; Avramova et. al, 2023; Georgieva et al., 2023: Avramova et al., 2023). The results obtained regarding pain before and after therapy prove that it is significantly reduced. The initial average values are 8±3.7, and at the end of the therapeutic course it is reduced to 3.5±0.65 according to the VAS scale.

Capacitive and resistive electrical transfer leads to an endogenous temperature increase of the treated structures (Brinlee et al., 2022; Czuppon et al., 2014). This leads to an increase in their blood supply, vasodilation and cell proliferation. This physiological response helps to remove inflammatory catabolites and drain the edema. The rapid therapeutic effect leads to the improvement of the functionality of the knee joint and the reduction of the patients' fear of relapses. Reduced joint swelling and pain allows for earlier mobilization into a better range of motion.

Following the intragroup analysis, in addition to pain, joint swelling measured in cm was also significantly reduced, as already mentioned. The pre-treatment mean value of the circumference of the knee was 38.7±083 cm, while the post-treatment mean value was 36.75±0.73 cm. The swelling in the knee joint is reduced by about 2 cm. This allows the range of motion in the joint to be restored much more quickly. To measure the range of motion in the joint, we applied standard goniometry. The results obtained after application of the therapeutic program including TECAR, show both flexion and extension restored movement to fully functional range. The resulting endogenous heat in the various structures around the joint, which is achieved with the two modes of application of the Capacitive and Resistive electric transfer, in addition to influencing the inflammatory and healing processes by fastening them, also affects the structures themselves. Proven TECAR therapy also increases their elasticity and supports their healing by preventing the appearance of adhesions between the different layers.

Muscle force, static and dynamic balance are also fundamental components affecting human movement performance (Tsvetkova-Gaberska, Pencheva, 2022). Regarding the muscle strength of flexors and extensors in the knee joint, a number of authors prove that it turns out to be one of the main factors for functional recovery and prevention of relapses. After ACL surgery, regaining lower limb strength (especially in the quadriceps and ischiocrural muscles) is a top priority, as persistent weakness can lead to altered gait mechanics, knee joint degeneration, and ultimately risk of re-injury and disability for return to sports activity (Brown et al., 2020). The importance of quadriceps strengthening after ACLR is irrefutable. Unfortunately, periodic and accurate means of objective assessment the strength of the quadriceps appears to be scarce. The isokinetic dynamometer turns out to be the most accurate and objective method for assessing muscle strength in such cases, but it is a rather expensive and inaccessible method for most specialists. The lack of objective measurement quadriceps strengthening may be among the most worrisome trends in rehabilitation. In the present study, we used the conventional method of manual muscle testing to get some overview and compare the muscle strength of athletes before and after therapy (Brinlee et al., 2022). The results obtained before the 6-weeks rehabilitation program regard to muscular strength of the knee flexors were 3.55±0.5 and for knee extensors 3.75±0.46. After the application of the specialized therapeutic program including TECAR therapy the results reached up to 4.8±0.38 for flexors and 4.9± 0.3 for extensors.

TECAR therapy has no direct effect on muscle strength, but in our opinion and a number of other authors it could have an indirect effect. The therapy we applied to the study contingent included a specialized

individualized work protocol including high-resistance exercises, proprioceptive training, and athlete-specific exercises. However, in order for this set of exercises to be successfully applied, it is necessary to reduce the pain and swelling and achieve a functional range of motion in the joint. In this regard, TECAR therapy has been proven to achieve a quick and reliable effect. This allows the early application of exercises and prevention of more serious muscle hypotrophy. On the other hand, capacitive and resistive electrical transfer results in influencing the cellular and structural level of the affected structures, including muscles. The endogenous heat created leads to a better blood supply to the muscle and, accordingly, to its more efficient work during exercise. The results obtained in terms of muscle strength are extremely important, because a number of secondary complications in the short and long term originate from muscle weakness following such trauma. Tight muscle weakness can lead to long-term osteoarthritis, impaired gait, re-injury or an inability to return to pre-injury sports level. Most notable are the results pertaining to reducing the functional disability (from high and moderate to low level). We used the Lower Extremity Functional Scale (LEFS) to assess the functional limits of the lower limb after an ACL reconstruction in athletes. Before treatment the mean level of LEFS was 69.59 ± 0.34 % and after 6 weeks of combined therapy with TECAR the LEFS level was 19.86 ± 0.52% (p=0.0001).

From a clinical point of view, there is a relationship between the various limiting factors in the knee joint after ACL reconstruction. As already mentioned, the reduction of pain and swelling allows achieving a greater range of motion and, accordingly, achieving better functionality of the affected lower limb. This trend is also confirmed by the results obtained in the present study. This led us to try to prove these dependencies by applying statistical correlation analysis.

Dainese et al., 2021 in their study "Association between knee inflammation and knee pain in patients with osteoarthritis", report that different inflammatory markers are associated with pain but the correlation ranges from weak to moderate, and the quality of evidence from conflicting to moderate. These results may be due to the fact that osteoarthritis is a chronic disease with a multifactorial nature and this makes it challenging to distinguish if a specific structure has a predominant role in evoking pain more than others.

We performed a correlation analysis of all the studied indicators. Although pain clinically influenced many of the other variables monitored, we did not find statistically significant correlations. In our opinion, the reason for this may be the fact that, in its essence, pain is extremely complex and can be of various origins. Pain scales are subjective because pain is a completely subjective sensation and cannot be measured objectively. Rupture of the anterior cruciate ligament is an acute condition accompanied by a strong inflammatory process that covers all structures in the knee complex. This also makes it difficult to pinpoint a specific structure that may be causing the pain in general. Due to the specificity of the scales used, we applied Spearman's rank correlation. No significant correlations were found between the majorities of the obtained values. However, after a detailed analysis of the data, a weak but statistically significant correlation was found between the strength of the knee extensors and the degrees of extension, as well as between the strength of the knee flexors and the lower extremity functional assessment scale. Regarding the dependence of the strength of the extensors of the knee joint (MMT of m. Quadriceps femoris) and the degrees of extension (Goniometry), a positive correlation was established (Spearman rank correlation 0.288; P = 0.025; two-tailed).

The correlation between m. Quadriceps strength and degrees of knee extension is likely due to two factors. On the one hand, the strong strengthening of the extensor muscles of the knee helps to achieve the last degrees of extension. Many studies prove the extreme importance of quadriceps strength after this type of injury. For example, Buckthorpe et al., 2019 describe different extensor muscle recovery strategies after ACL reconstruction as a main priority for the rehabilitation program (Buckthorpe et al., 2019). In addition, full recovery of this musculature is of paramount importance to prevent a number of complications such as impaired gait mechanics, risk of developing knee osteoarthritis and inability to return to sports or reach the pre-injury level of sports (Filbay et al., 2019). On the other hand, from a physiological point of view, we know that the contraction of a given muscle, in this case the Quadriceps, leads to a reciprocal inhibition and relaxation of its antagonist - the Ischiocrural musculature. Relaxation of the knee flexors allows full extension in the knee joint.

Another correlation was found, between the strength of the knee flexors and the lower extremity functional scale. It turns out that, although weak, this dependence is statistically significant. In most of the activities included in the functional scale (LEFS), the extensors of the knee joint are actively involved. Good muscle strength and neuromuscular control between flexors and extensors, as well as good coordination and balance, are necessary for these activities to be possible and performed correctly. The knee extensors and flexors are important dynamic stabilizers and the weakness in these muscles could impair knee joint stability. The knee extensors and flexors cross the knee joint. Weakness in these muscles can directly alter tibiofemoral biomechanics. This can contribute to joint degeneration. In fact, knee extensor weakness is thought to limit its ability to absorb weight, which accelerates increased stress on the articular cartilage and thus can lead to joint degeneration. Additionally, the knee flexor strength deficits that are present when individuals return to full activity can also be dangerous because the knee flexors impede translation of the tibia, a known factor in ACL injury (Thomas et al., 2013). The positive correlational dependencies established in this way enable us to claim that we could directly influence some limiting factors related to others. For example, TECAR therapy affects the inflammatory process and stimulates healing processes. This leads to reduction of pain and joint swelling. As a

consequence, the range of motion is increased and the increased blood supply to the motor muscles of the knee joint leads to the prevention of their hypotrophy and the faster recovery of their strength. TECAR therapy in combination with a specialized rehabilitation program improve the overall function of the joint and the affected lower limb in young athletes.

Conclusions:

In our previous randomized controlled study, we compared the results obtained after carrying out a specialized rehabilitation program of two groups of athletes after reconstruction of ACL. For the EG, we included TECAR procedures, while for the patients from the CG, we did not. We reported a statistically significant improvement in EG patients at the end of the therapeutic course in all obtained variables. To confirm the positive effect of TECAR, we performed a more detailed intragroup analysis of the results and looked for a correlation between some of them.

One of the strengths of the study is that the patient cohort was multi-sport athletes at high risk for ACL injury and subsequent reconstruction using a variety of proven operative methods. Given this, we can argue that the results are to some extent generalizable and widely applicable. Based on the intragroup analyses, we could safely claim that TECAR therapy in combination with the specialized rehabilitation program leads to an improvement of all analyzed limiting factors such as pain, edema, range of movement and muscle strength. This in turn improves the overall function of the affected knee joint. Correlation analysis showed weak but still statistically significant relationships between muscle strength of flexors and extensors, range of motion and joint functionality. This statistically significant correlation helps us to orient the rehabilitation program to certain indicators directly related to the maximally rapid functional recovery of the joint and return of the athlete to their previous sports activity.

In our opinion, TECAR therapy could be a good addition to the rehabilitation program for the recovery of athletes after ACL reconstruction.

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