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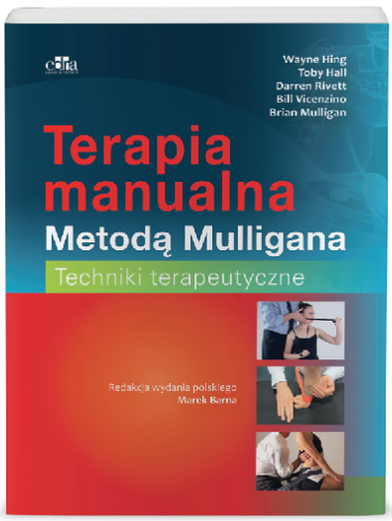

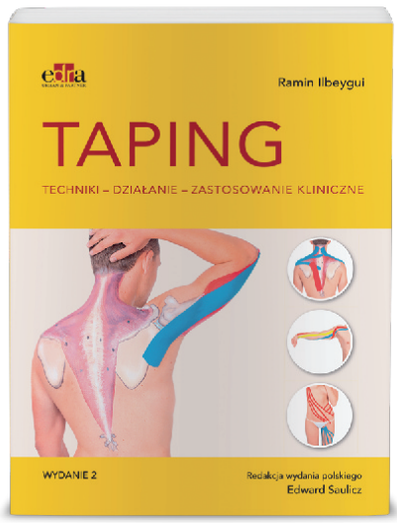

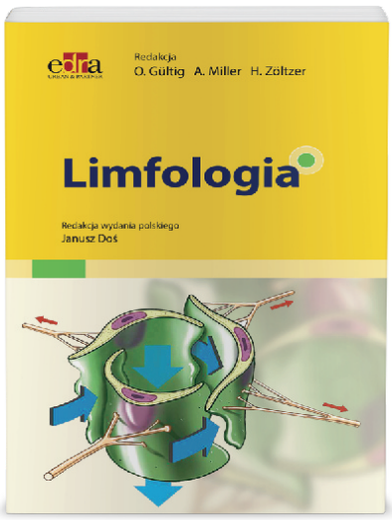

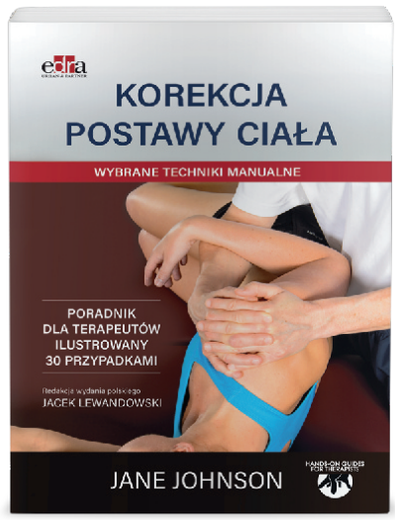

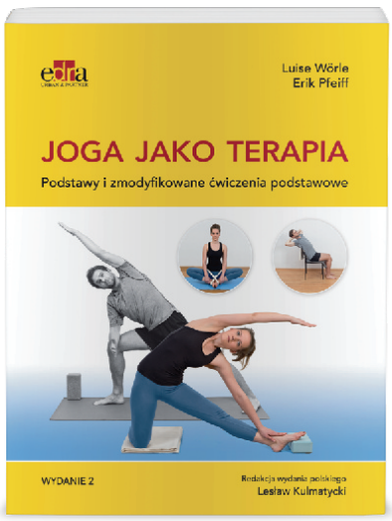

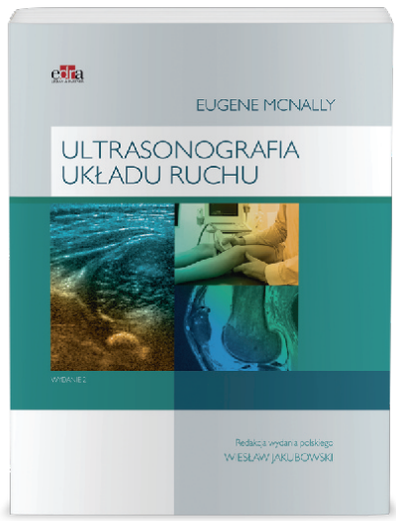

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Zastosowanie prądów wielkiej częstotliwości w leczeniu pacjentów z chorobą zwyrodnieniową stawów kolanowych

Application of high frequency currents in treatment of patients with knee osteoarthritis

高频电流在膝关节骨性关节炎患者治疗中的应用

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Streszczenie
Wstęp. Ciepło endogenne jest powszechnie stosowane w leczeniu pacjentów z chorobą zwyrodnieniową stawów kolanowych. Rozwój technologii umożliwia nowe sposoby aplikacji prądów wysokiej częstotliwości.
Celem pracy jest ocena skuteczności prądów wielkiej częstotliwości aplikowanych różnymi metodami w leczeniu pacjentów z chorobą zwyrodnieniową stawów kolanowych.
Materiał i metody. Badania przeprowadzono na grupie 111 osób z chorobą zwyrodnieniową stawów kolanowych, spośród których wyodrębniono dwie grupy. Grupę badaną stanowiło 61 osób poddanych terapii prądami wysokiej częstotliwości z wykorzystaniem urządzenia Thermo TK. Grupę porównawczą stanowiło 50 osób, poddanych zabiegom diatermii krótkofalowej. Ocenę skuteczności terapii przeprowadzono na podstawie skali VAS, skali Laitinena, obwodu i zakresu ruchu w stawie kolanowym.
Wyniki. W obu grupach stwierdzono po terapii istotne statystycznie ($p < 0,0001$) zmniejszenie dolegliwości bólowych wg skali Laitinena (mediana (zakres międzykwartylowy IQR) odpowiednio przed i po terapii: w grupie badanej: 7 (6-8) pkt vs 3 (2-6) pkt oraz w grupie porównawczej: 8 (6-10) pkt vs 3.5 (2-7) pkt). Dodatkowo, w grupie badanej zaobserwowano istotne statystycznie ($p = 0,0031$) zmniejszenie częstości stosowania leków przeciwbólowych. Po terapii w każdej z grup odnotowano również istotne statystycznie ($p < 0,0001$) złagodzenie dolegliwości bólowych wg skali VAS podczas chodzenia po płaskiej powierzchni i po schodach. Zmniejszeniu uległ także obwód przez staw kolanowy ($p < 0,0001$), natomiast istotnie zwiększył się zakres ruchu zgięcia ($p < 0,0001$). Czas trwania efektu analgetycznego w obu grupach był podobny.
Wnioski. 1. Bez względu na rodzaj aplikacji, prądy wysokiej częstotliwości wpływają na zmniejszenie dolegliwości bólowych oraz poprawę zakresu ruchu stawów kolanowych u pacjentów z chorobą zwyrodnieniową. 2. Efekt przeciwbólowy terapii w obu grupach nie był trwały.

Słowa kluczowe:
stawy kolanowe, choroba zwyrodnieniowa, prądy wielkiej częstotliwości

Abstract
Introduction. Endogenous heat is widely used in the treatment of patients with knee osteoarthritis. The development of technology enables new methods of applying high frequency currents.
The purpose of the work is to assess the effectiveness of high frequency currents applied by various methods in the treatment of patients with knee osteoarthritis.
Material and methods. The study was conducted on a group of 111 patients with knee osteoarthritis, of which two groups were distinguished. The studied group consisted of 61 patients subjected to high-frequency therapy using the Thermo TK device. The control group consisted of 50 patients who underwent shortwave diathermy treatment. Assessment of the effectiveness of therapy was carried out on the basis of the VAS scale, Laitinen scale, perimeter and range of motion in the knee joint.
Results. Both groups displayed a statistically significant ($p <0.0001$) reduction in pain after the therapy according to the Laitinen scale (median (interquartile range IQR), respectively before and after the treatment: in the study group: 7 (6-8) scores vs. 3 (2-6) scores and in the control group: 8 (6-10) scores vs. 3.5 (2-7) scores). In addition, a statistically significant ($p = 0.0031$) reduction in the frequency of analgesics was observed in the study group. After treatment, in each of the groups, statistically significant ($p <0.0001$) alleviation of pain symptoms according to the VAS scale was also observed while walking on a flat surface and stairs. Circumference through the knee joint was also decreased ($p <0.0001$), while the extent of the bending movement significantly increased ($p <0.0001$). The duration of the analgesic effect in both groups was similar.
Conclusions. 1. Regardless of the type of application, high frequency currents reduce pain and improve the range of knee joint motion in patients with osteoarthritis. 2. The analgesic effect of the therapy in both groups was not permanent.

Key words:
knee joints, degenerative disease, high frequency currents

摘要
前言。内源性热源于膝关节骨性关节炎患者治疗中广泛使用，技术的发展促成高频电流新方法的应用。
研究目的在评估治疗膝关节骨性关节炎患者的各种应用方法中，使用高频电流的有效性。
材料及方法。该研究针对 111 名膝关节骨性关节炎患者进行，将其分为二组，研究组中有 61 名，他们接受使用 Thermo TK 设备的高频电流治疗。对照组中有 50 人，他们接受短波透热治疗。疗效根据 VAS 量表、莱蒂宁量表、膝关节周长和活动范围进行评估。
结果。两组经治疗后均确认根据莱蒂宁量表（治疗前后的中数（四分位间距 IQR）：研究组：7（6-8）分对 3（2-6）分，对照组：8（6-10）分对 3.5（2-7）分）所测量的疼痛减轻具统计学意义（$p<0.0001$）。此外，在研究组中观察到具统计学意义（$p=0.0031$）的止痛药使用频率降低。治疗后，两组根据 VAS 量表测量在平坦表面行走和上楼梯时的疼痛症状缓和具统计学意义（$p<0.0001$），膝关节周长也减少（$p<0.0001$），而屈曲运动范围却显著增加（$p<0.0001$）。两组的镇痛效果持续时间类似。
结论。1. 无论何种类型的应用，高频电流都能减轻骨性关节炎患者的疼痛并改善其膝关节运动范围。2. 两组治疗的镇痛效果均不持久。

关键词：
膝关节、骨关节炎、高频电流

Introduction

Osteoarthritis is one of the most frequent diseases of the musculoskeletal system, leading to the destruction of joint cartilage. According to WHO, it affects as much as 10% of the population above 60 years of age [1]. Gonarthrosis ranks third behind degenerative changes in the spine and hip. It is estimated that it affects 19-28% of people over 45 years of age and about 37% of people over 60 [2]. Knee osteoarthritis causes pain, limitation of mobility and stiffness of the joint, which lead to limitation of the gait function. Problems with locomotion impede activity in everyday life and reduce the patient's quality of life [1-5].

Physiotherapy is commonly used in the treatment of knee osteoarthritis [2, 5]. Individually matched motion therapy supplemented by physical procedures affects the alleviation of symptoms of the disease [6-9]. The use of physical stimuli reduces pain and inflammation, which gives better conditions for conducting exercises and allows an increase in the level of physical activity [8-12]. Cryotherapy, electrotherapy, magnetic field, ultrasound, laser are treatments whose effectiveness has been confirmed in scientific reports [5, 10-12].

Frequency currents have been used in medicine for a long time. The mechanism of their impact is the subject of many studies [8-13]. The electromagnetic field, which arises as a result of the flow of currents with frequencies from the megahertz band, generates a number of changes in the human body. Absorbed energy is converted into heat in deeply located tissues. There occurs overheating, which is called diathermy. Its intensity depends on the degree of vascularity, thermal capacity and ionic conductivity of tissue electrolytes. Under the influence of endogenous heat, the blood vessels dilate, improve blood supply and tissue absorption. Acceleration of metabolic processes at the cellular level stimulates regeneration. Thanks to the reduction of neuromuscular excitability, an effect of reducing muscle pain and tension is observed. As a result of the procedure within the joint covered by osteoarthritis, inflammation and exudation are reduced [13-15].

Originally high frequency currents were applied to the body in the form of long-wave diathermy treatments. However, unfavorable symptoms after exposure and uneven tissue overheating resulted in the introduction of short waves for treatment. Currently, the short-wave diathermy most often uses an electromagnetic field with a frequency of 27.12 MHz and a wavelength of 11.05 m. Depending on the method, the procedure consists in placing an object overheated between two capacitor covers or within the operation of the induction electrode [14, 15].

The development of technology has enabled the introduction of new forms of therapy with high frequency currents. An example is the ThermoTK device, which uses an electromagnetic field at 460 kHz and 540 kHz. The treatment consists in performing a massage with an applicator using a special cream. The second electrode, neutral, is placed on the opposite side of the area to be treated. The advantage of this therapy is the ability to accurately target it to the site of lesions without charging the whole body with an electromagnetic field.

Both methods elicit a pleasant feeling of warmth generated in the tissues during the procedure. However, they differ in the way of application.
The work aims to evaluate the effectiveness of high frequency currents applied by various methods in the treatment of patients with knee osteoarthritis.

Material and methods

The study involved a total of 111 people (79 women and 32 men) with chronic pain syndromes of the knee joints due to degenerative disease. The average age of the respondents was 54.3 ± 9.6 years, half of the patients were at most 54 years old (IQR: 47-60 years). The average duration of pain was 5.4 ± 3.9 years, and in half of the subjects did not exceed 5 years (IQR: 3-6 years). Two groups were distinguished from all the subjects.
The study group consisted of 61 people (55%, including: 44 women and 17 men), subjected to high-frequency therapy using the Thermo TK device. The average age in this group was 54.5 ± 9.4 years, and half of the patients were 54 years or older (IQR: 48-59 years).
The comparative group consisted of 50 people (45%, including: 35 women and 15 men), subjected to short-wave diathermy treatment. The mean age in this group was 54.2 ± 9.9 years, and in the case of half of the patients it was not greater than 52.5 years (IQR: 47-60 years).
The groups did not differ significantly in terms of their sex structure and age ($p = 0.8052$ and $p = 0.8019$ respectively). There were no significant differences between the groups from the point of view of the body mass index ($p = 0.1266$); each group was dominated by overweight people (respectively: 44.3% in the study group and 40.0% in the control group).
Approval of the Bioethics Commission No. RNN/85/15/EC was obtained for conducting the tests. All patients were informed about the principles of high-frequency currents, signed a written consent for treatment and inclusion in the study. Both groups of patients underwent 10 procedures using high frequency currents. In the study group treatments for knee joints were made with the ThermoTK device. A resistance mode with a frequency of 460 kHz was used for therapy. In the control group, BTL short-wave diathermy therapy was used. Treatments were performed daily. In order to evaluate the results, the patients were examined according to the established test protocol before and after a series of treatments. The study included assessment of the circumference, range of knee joint motion, pain assessment with VAS scale and Laitinen scale and gait assessment. Additionally, after 12 months from the end of the therapy, information on the duration of the analgesic effect obtained was collected. The obtained data was subjected to statistical analysis.

Statistical analysis

Quantitative variables are described by means of mean and standard deviation (in case of normality of distribution) and order statistics: median (Me) and interquartile range (IQR) as well as minimum and maximum (Min-Max). The

normality of variables was verified using the Shapiro-Wilk's test for normality. For categorical variables the number of observations (N) with the corresponding percentage (%) was provided.

To compare two independent groups, the Student's t-test was used (in the case of normality of distribution in the compared groups) or the non-parametric Mann-Whitney U test (in the situation of lack of normality). A two-way ordinal repeated measures ANOVA was used to compare groups with repeated measurements (before and after treatment).

In the case of qualitative variables, Pearson's chi-squared test of independence and McNemar-Bowker's test were used to compare groups between each other and over time.

Duration of the analgesic effect after treatment was assessed using the Kaplan-Meier curves. The log-rank test was used to compare curves from two groups.

Statistically significant results were assumed at $p < 0.05$. The calculations were performed using the statistical package STATISTICA PL 13.3 and the R environment.

Results

The duration of pain was significantly longer ($p = 0.0052$) in the control group and in the case of half of the patients was at most 5 years (IQR: 4-8 years). In the study group, half of the patients suffered from pain no more than 4 years (IQR: 2-5 years). The obtained results are shown in Fig. 1.

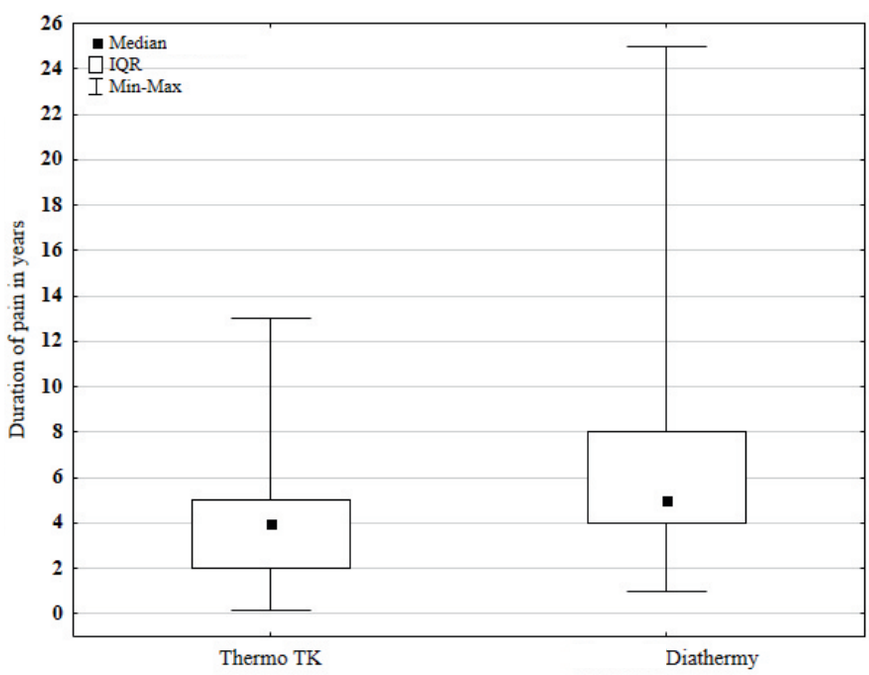

Fig. 1. Comparison of the duration of pain in the analyzed groups

The characteristics of the circumference through the knee joint before and after therapy in both groups are presented in Tab. 1. There are no statistically significant differences between groups due to the size of circumference both before and after therapy. In both groups, a statistically significant ($p < 0.0001$) reduction in the circumference after treatment was found. In the study group before therapy, in half of the patients the circumference did not exceed 40 cm

(IQR: 37-42 cm) and after therapy – 39 cm (IQR: 36-41 cm). In the comparison group before therapy, in half of the patients the size of the circumference did not exceed 39 cm (IQR: 37-41 cm) and after therapy - 37.8 cm (IQR: 36.5-41 cm).

Tab. 1. Circumference through the knee before and after therapy in compared groups

Group	Measure	Circumference		p-value (before vs. after)
		Before therapy	After therapy	
Thermo TK	Me (IQR) Min-Max	40 (37-42) 32-51	39 (36-41) 30-52	< 0.0001
Diathermy	Me (IQR) Min-Max	39 (37-41) 32-51	37.8 (36.5-41) 31-50	< 0.0001
p-value (comparison of groups)		0.9924	0.7830	x

Tab. 2 presents the results of the assessment of ranges of bending movements before and after therapy in the compared groups of patients. There were no statistically significant differences between the groups before and after therapy. In both groups, a statistically significant increase in the extent of bending movement after therapy was observed.

Tab. 2. Bending motion ranges before and after therapy in compared groups

Group	Measure	Bending		p-value (before vs. after)
		Before therapy	After therapy	
Thermo TK	Me (IQR) Min-Max	105 (100-115) 70-135	110 (110-120) 70-135	< 0.0001
Diathermy	Me (IQR) Min-Max	100 (90-110) 70-130	110 (100-120) 80-135	< 0.0001
p-value (comparison of groups)		0.3119	0.7803	x

In the study group (Thermo TK) before therapy, the bending range did not exceed 105° in half of the patients (IQR: 100°-115°); after therapy, a statistically significant ($p < 0.0001$) increase in the range of motion to (on average) 110° was noted (IQR: 110°-120°). Similarly, in the control group (diathermy) before therapy, in half of patients the range of flexion movement did not exceed 100° (IQR: 90°-110°); after therapy, a statistically significant ($p < 0.0001$) increase in the extent of bending to 110° was noted (IQR: 100°-120°).

The range of bending movement in both groups was 0° in most patients. In the study group, abnormal volume of the extension movement was recorded in three patients before the therapy. After treatment, two of them showed an improvement in the extensor movement range, from 10° to 0° and from 20° to 15°. In the control group, incorrect values of the extension movement range were observed in two patients (5 and 10°), after the therapy, no improvement was noted in these patients.
Assessment of pain symptoms according to the VAS scale while walking on a flat surface and on the stairs before and after treatment in both groups of patients is presented in Tab. 3. There were no statistically significant differences between the groups before and after the therapy. However, in each group, significant ($p < 0.0001$) reduction in pain after treatment was observed, both when walking on a flat surface and when climbing the stairs.

Tab. 3. Assessment of pain when walking on a flat surface and stairs according to the VAS scale before and after therapy in the compared groups

Group	Measure	Walking on flat surface		p-value (before vs. after)	Climbing the stairs		p-value (before vs. after)
		Before therapy	After therapy		Before therapy	After therapy	
Thermo TK	Me (IQR) Min-Max	5 (4-5) 0-8	2 (1-3) 0-5	< 0.0001	7 (6-8) 1-10	3 (2-5) 0-9	< 0.0001
Diathermy	Me (IQR) Min-Max	4 (3-6) 0-9	1 (0-3) 0-6	< 0.0001	6 (5-8) 2-10	3 (2-5) 0-6	< 0.0001
p-value (comparison of groups)		1.0000	0.2648	x	0.2583	0.6037	x

In the study group (Thermo TK), half of the patients assessed pain while walking on a flat surface before therapy for at most 5 points (IQR: 4-5 scores) and after therapy a maximum of 2 points (IQR: 1-3 scores), while in the case of walking the stairs – before therapy, at most 7 scores (IQR: 6-8 scores) and after therapy a maximum of 3 scores (IQR: 2-5 scores). In the control group (diathermy), when walking on a flat surface, half of the patients assessed the severity of pain according to the VAS scale before the therapy at no more than 4 scores (IQR: 3-6 scores) and after therapy – no more than 1 score (IQR: 0-3 scores). Pain while climbing the stairs was assessed by half of patients for at most 6 scores before therapy (IQR: 5-8 scores) and after therapy – no more than 3 score (IQR: 2-5 scores).
Information on the frequency of analgesics in both analyzed groups is summarized in Tab. 4. The groups differed significantly ($p <0.0001$) due to the need to use analgesics before therapy. In the comparative group, a higher percentage of patients receiving high and very high doses was recorded than in the study group - respectively: 24% vs. 8.2%. After treatment, the diffe-

rence between groups is not statistically significant ($p = 0.0771$).
In addition, a statistically significant ($p = 0.0031$) reduction in the frequency of analgesics was observed in the study group after treatment. The percentage of patients who did not report the need to use medication increased significantly (respectively: 21.3% before therapy vs 72.1% after therapy).

Tab. 4. The use of analgesics before and after therapy in the compared groups

Group	Analgesics before therapy	Analgesics after therapy						
		without medication	ad hoc	repeatedly small doses	repeatedly large doses	repeatedly very large doses	Total N (%)	p-value (before vs. after)
Thermo TK	without medication	13	0	0	0	0	13 (21.3%)	0.0031
	ad hoc	27	13	0	0	0	40 (65.6%)	
	repeatedly small doses	2	1	0	0	0	3 (4.9%)	
	repeatedly large doses	0	0	2	0	0	2 (3.3%)	
	repeatedly very large doses	2	0	0	1	0	3 (4.9%)	
	Total N (%)	44 (72.1%)	14 (23.0%)	2 (3.3%)	1 (1.6%)	0 (0.0%)	61	
Diathermy	without medication	17	0	0	0	0	17 (34.0%)	0.2544
	ad hoc	7	3	0	1	0	11 (22.0%)	
	repeatedly small doses	3	4	3	0	0	10 (20.0%)	
	repeatedly large doses	1	5	1	0	0	7 (14.0%)	
	repeatedly very large doses	0	0	4	1	0	5 (10.0%)	
	Total N (%)	28 (56.0%)	12 (24.0%)	8 (16.0%)	2 (4.0%)	0 (0.0%)	50	
p-value (comparison of groups)		before therapy: < 0.0001			after therapy: 0.0771			x

The assessment of pain symptoms according to the modified Laitinen scale before and after therapy in the analyzed groups is presented in Tab. 5. The examined groups did not differ statistically significantly before and after the therapy, while a significant ($p < 0.0001$) decrease in post-therapy symptoms was found in each group.

Half of the patients from the test group (Thermo TK) assessed pain complaints according to the Laitinen scale before therapy for at most 7 scores (IQR: 6-8 scores), and after therapy – at most 3 scores (IQR: 2-6 scores). In the comparative group (diathermy), before therapy, half of the patients reported pain at the level of at most 8 scores (IQR: 6-10 scores), and after therapy – at most 3.5 scores (IQR: 2-7 scores).

Tab. 5. Assessment of pain symptoms according to the modified Laitinen scale before and after therapy in the compared groups

Group	Measure	Pain assessment		p-value (before vs. after)
		Before therapy	After therapy	
Thermo TK	Me (IQR)	7 (6-8)	3 (2-6)	< 0.0001
	Min-Max	3-15	0-12	
Diathermy	Me (IQR)	8 (6-10)	3.5 (2-7)	< 0.0001
	Min-Max	4-15	0-11	
p-value (comparison of groups)		0.0830	0.8803	x

After 12 months from the end of the therapy, information on the duration of the analgesic effect obtained was collected among patients from both groups.

In the study group (Thermo TK), the average duration of analgesic effect was 4.3 ± 3.2 months. In half of the patients, the analgesic effect lasted at most 4 months (IQR: 2-6 months). Most often (10 patients, 16.4%) the effect lasted for 3 months. In the control group (diathermy), the mean duration of analgesic effect was 4.4 ± 3.4 months. In half of the patients, the analgesic effect lasted at most 3 months (IQR: 2-7 months). Most often (9 patients, 18.0%) the effect lasted for 3 months.

The Kaplan-Meier survival curves for both groups are shown in Fig. 2. The survival curves obtained do not differ significantly (log-rank test, $L = 0.0070$, $p = 0.9944$).

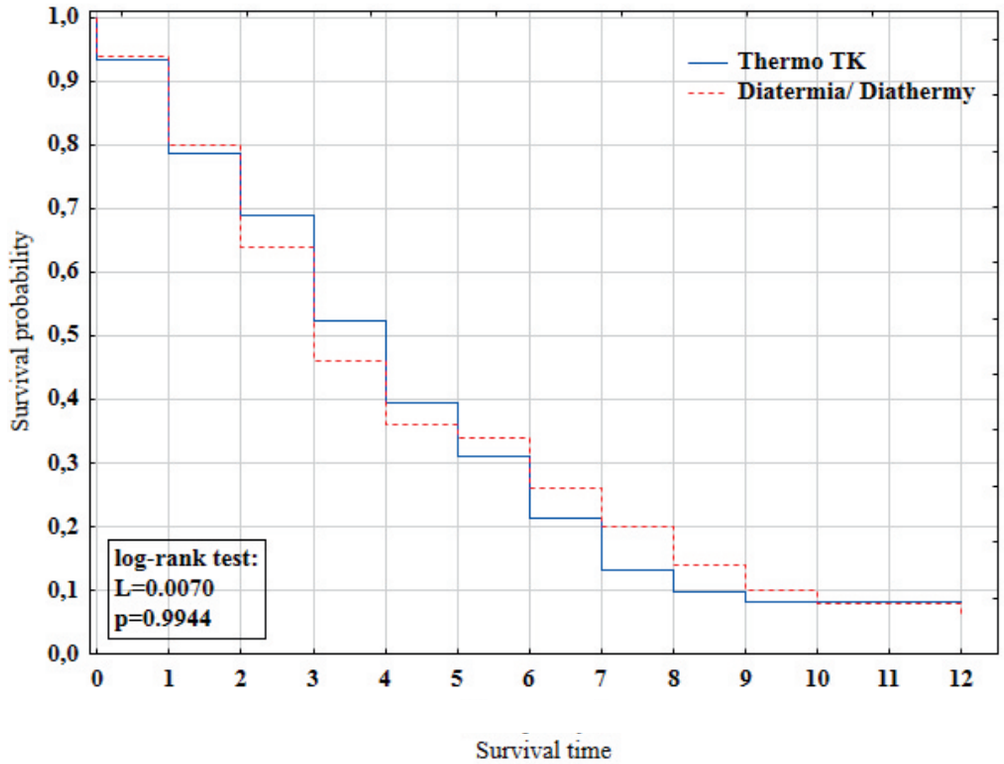

Fig. 2. Kaplan-Meier survival curves in the selected groups

Discussion

Assessment of the effectiveness of high-frequency therapy in the treatment of symptoms of gonarthrosis has been the subject of many scientific studies. All authors agree that as a result of absorbed energy, the temperature of deeply located tissues increases, and endogenous heat generates a number of changes in the tissues [8, 9, 11, 12].

The research shows that pain assessment based on the Laitinen scale and the VAS scale conducted before and after the end of therapy in both groups indicates a reduction in pain. The analgesic effect was observed both during walking on a flat surface and up the stairs. The applied therapy allowed to limit the amount of analgesics to be taken. Kościelny et al. demonstrated a reduction in pain due to high-frequency electromagnetic field therapy applied through massage before exercise [11].

Lowering the level of pain in the knee joints under the influence of shortwave diathermy was also observed by Atamaz et al. and Boyaci et al. [12, 16].

Rabini et al. compared the effectiveness of exo and endogenous heat in patients with knee osteoarthritis. Based on the obtained results, they found a reduction in pain and improvement of the functional status in the group subjected to short-wave diathermy treatment, and the beneficial effect of the therapy lasted at least 12 months [17]. The research shows that the analgesic effect of both treatments was not as durable. The reduction of pain lasted on average for 4 months.

The ongoing degenerative disease in the joint is conducive to the formation of exudate and increase in the contour of the joint. As a result of the endogenous heat generated in tissues, both in the group with Thermo TK and DKF therapy, there was a reduction in edema within the knee joint affected by gonarth-

rosis. Analysis of the obtained results also showed a statistically significant increase in the range of bending movement after therapy. Despite the lack of kinesitherapy, this effect was caused by the reduction of pain, swelling and reflex tension of soft tissues.
The meta-analysis carried out by Laufer et al. also confirms the effect of pain reduction due to endogenous heat resulting from short-wave diathermy in gonarthrosis [18]. A similar conclusion based on the literature review was made by Wang et al. However, the authors point out that this did not affect the function of knee joints affected by osteoarthritis [19].
The best effects of treatment have been presented in reports describing high-frequency therapy combined with kinesitherapy. Pain reduction, greater exercise efficiency and improved knee joint function under the influence of DKF were found by Cetin et al. [9].
The different results of short-wave diathermy therapy were presented by Akyol et al. Based on the studies conducted, a group of 40 patients with knee arthrosis stated that the additional use of DKF in the group performing isokinetic exercises had no effect on improvement [8].
According to the analysis of the results of research and scientific reports, the effectiveness of high frequency currents used in the treatment of knee osteoarthritis is ambiguous and requires further randomized trials.

Conclusions

1. High frequency currents show a significant impact on reducing pain and the amount of medication taken for knee joint discomfort.
2. The therapy applied significantly reduced swelling and improved the range of knee joint motion.
3. The sustained improvement in both methods of applying high frequency currents is not long-standing.

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