Effectiveness of Local Cryotherapy Treatment with the Use of Carbon Dioxide and Liquid Nitrogen Among Patients with Low Back Pain Syndrome

Skuteczność zabiegów kriostymulacji miejscowej z użyciem dwutlenku węgla oraz ciekłego azotu w przebiegu zespołów bólowych kręgosłupa lędźwiowego

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Keywords
cryotherapy, liquid nitrogen, carbon dioxide, low back pain syndromes

Abstract
Introduction: Low back pain syndromes (LBPS) are common. One of the methods of treating LBPS is local cryotherapy, which can be based on various cooling substances. In the available literature, it is suggested that effective cold treatment may depend on the type and temperature of the cooling substance used.
Research objective: The aim of the study was to evaluate the effectiveness of 2 local cryotherapy (Carbon Dioxide and Liquid Nitrogen) types among patients with low back pain syndrome (LBPS).
Materials and methods: The study included 60 patients diagnosed with chronic LBPS of discopathic origin. Patients were randomised into 2 study groups. Local cryotherapy treatment with Carbon Dioxide was used in the 1st group (G1), while in the 2nd (G2), cryotherapy treatment with applied Liquid Nitrogen. Two measurements were taken, before and after 2 weeks treatment. The following were used for assessment: centralisation of symptoms (Pain Drawings), pain intensity (Numeral Rating Scale), duration of the current pain episode (Quebec Task Force Classification), level of disability (Roland-Morris Disability Questionnaire), quality and intensity of subjective pain (McGill Pain Questionnaire), patients' emotional state (Adjectival Scale for Testing Emotions) and self-efficacy related to pain (Pain Self-Efficacy Questionnaire). Statistical analysis was performed via the Student's *t*-test for dependent and independent samples.
Results: In both study groups, the perceived pain was either completely eliminated or centralised to the spine, hip joint and buttock. The level of pain, disability and pain-related self-efficacy decreased significantly, regardless of the therapy used. In terms of these variables, no greater therapeutic efficacy was demonstrated with either cryostimulation treatment. Qualitative assessment of pain and emotions (especially anxiety and anger) decreased significantly in G1 and G2. However, in the nitrogen-treated group, a significantly greater improvement was noted for WOB:OC, anger and anxiety scores (for these variables, the G2 group started from a higher level prior to therapy).
Conclusions: Both analysed treatments are equally effective in terms of variables such as: centralisation of symptoms, level of pain intensity, disability, joy, self-efficacy related to pain, as well as the majority of the analysed MPQ indicators. Cryostimulation with liquid nitrogen may be more effective, but only in improving the WOB: OC index of the MPQ questionnaire and the level of anger and anxiety. Nonetheless, the obtained results do not allow for definitive confirmation of these results. The use of both cryostimulation treatment methods may assist in the treatment process of LBPS.

Słowa kluczowe
kriostymulacja, azot, dwutlenek węgla, lędźwiowe zespoły bólowe

Streszczenie
Wprowadzenie: Zespoły bólowe kręgosłupa lędźwiowego (ZBKL) występują powszechnie. Jedną z metod leczenia ZBKL jest kriostymulacja miejscowa, która może bazować na różnych substancjach chłodzących. Dostępna literatura sugeruje, że efektywne leczenie zimnem może zależeć od rodzaju i temperatury stosowanej substancji chłodzącej.

The individual division of this paper was as follows: A – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

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Cel: Celem pracy była ocena skuteczności leczenia dwóch zabiegów kriostymulacji, to jest z użyciem dwutlenku węgla oraz ciekłego azotu w przebiegu zespołów bólowych kręgosłupa lędźwiowego (ZBKL).
Materiał i metoda: Do badania włączono 60 pacjentów z ZBKL o podłożu dyskopatycznym, których podzielono losowo na dwie grupy. W pierwszej grupie (G1)zastosowano kriostymulację dwutlenkiem węgla, a w drugiej (G2) kriostymulację ciekłym azotem. Zarówno przed dwutygodniową terapią, jak i po jej zakończeniu określono topografię dystalnych objawów (Pain Drawing), intensywność bólu (NRS), długość trwania obecnego epizodu bólowego (QTF), poziom niepełnosprawności (RMQ), aspekty jakościowe bólu (MPQ), stan emocjonalny chorego (Przymiotnikowa Skala do Badania Emocji) oraz skuteczność związaną z bólem (PSEQ). Wykonano analizę statystyczną wykorzystując test t-Studenta dla prób zależnych i niezależnych.
Wynik: Odczuwane dolegliwości bólowe uległy całkowitej eliminacji albo scentralizowały się do kręgosłupa, stawu biodrowego i pośladka w obu grupach badanych. Poziom bólu, niepełnosprawności oraz samoskuteczności związanej z bólem zmniejszył się istotnie, niezależnie od zastosowanej terapii. W zakresie tych zmiennych nie wykazano większej skuteczności terapeutycznej jednego z zabiegów kriostymulacji. Jakościowa ocena bólu i emocje (szczególnie lęk i gniew) zmniejszyły się istotnie w G1 i G2. Jednak grupa leczona azotem uzyskała istotnie większą poprawę w zakresie wskaźników WOB:OC, gniewu i lęku (w przypadku tych zmiennych grupa G2 startowała z wyższego poziomu przed terapią).
Wnioski: Oba analizowane zabiegi są podobnie skuteczne w zakresie takich zmiennych, jak: centralizacja objawów, poziom natężenia bólu, niepełnosprawności, radości oraz samoskuteczności związanej z bólem, jak również większości analizowanych wskaźników MPQ. Kriostymulacja ciekłym azotem może być bardziej efektywna jedynie w poprawie wskaźnika WOB:OC kwestionariusza MPQ oraz poziomu gniewu i lęku, jednak uzyskane wyniki nie pozwalają na ostateczne potwierdzenie tych rezultatów. Stosowanie obu zabiegów kriostymulacji może wspomagać proces leczenia ZBKL.

INTODUCTION

Low back pain syndromes (LBPS) are a common population-based problem, especially in industrialised countries[1,2]. They affect both women and men of all ethnicities, and it has been suggested that female gender is more predisposed[3,4]. The incidence of LBPS increases with age, the highest values occurring between 35 and 49[5]. Within 6 weeks of the onset of LBPS, pain symptoms subside in 80 to 90% of people, while in the remaining 10%, they assume chronic form[6]. LBPS, however, are characterised by a tendency to relapse or worsen symptoms[2]. The results of epidemiological studies also suggest that the incidence of LBPS will increase in coming years[2,7].

There are many treatments available for LBPS. We can distinguish, among others, specialist, international physiotherapeutic methods (e.g. manual therapy, the PNF or McKenzie method)[8,9] and traditional therapy[10,11]. The latter includes medications, including anti-inflammatory and analgesic ointments[10], classical massage, kinesiotherapy and physical therapy[11]. Physiotherapeutic treatments are based on various types of physiological reactions occurring in the body under the influence of a physical stimulus[12]. One of the strong stimulating factors is cold, and treatments with its use are generally referred to as cryotherapy[13]. Among them, local and whole-body cryotherapy can be distinguished[12]. The healing effect of these treatments is based on the body's reaction to cold, thus, on a thermoregulation mechanism controlled by the autonomic nervous system. When the skin is exposed to the cold factor, the so-called Lewis Hunting Reaction occurs, consisting of 2 phases. The 1st stage, which is the body's defence reaction against excessive cooling, is the narrowing of blood vessels in the skin and subcutaneous tissues. During the 2nd phase, these tissues become hyperemic due to the dilation of blood vessels[12,14]. The above stages are wave-shaped and alternating. The result of this phenomenon is the occurrence of beneficial physiological reactions, such as those: analgesic, anti-inflammatory, anti-swelling, and the regulation of muscle tone[12,14].

Various types of cooling substances are used in local cryotherapy, including nitrogen and carbon dioxide, also known as cryogenic liquids[15]. The comparison of both treatments in terms of methods for lowering temperature, safety and costs of their execution, availability, effectiveness, frequency of their implementation and durability of the apparatus used shows some similarities and differences.

The physicochemical properties of these substances enable their safe use. The methods of lowering their temperature in modern devices, however, are based on different physical phenomena[15]. In treatments with the use of carbon dioxide, the temperature of this liquid is reduced by adiabatic expansion. The above phenomenon, called the Joule-Thomson effect, takes place in specially-designed applicators and causes their cooling down to about -70°C. On the other hand, in an apparatus cooled with liquid nitrogen, the liquid changes to a gas. Liquid nitrogen has a low boiling point (-195.8°C) and, at the same time, a high heat of vaporisation. The liquefied gas at the tip of the applicator washes its inner surface and evaporates, while extracting heat from the environment. As a result, this part of the device is cooled down to a temperature equalling the boiling point of liquid nitrogen. Then, the temperature at the nozzle outlet is between -160°C and -196°C[15,16].

The analysis of other safety aspects showed, *inter alia*, that during the treatment with liquid nitrogen, the feeling of cold is stronger, which may cause discomfort to some patients or frostbite[12,15]. Despite this, Bęben and Kiljański[17] observed that the degree of cooling the skin on the hand, examined with a thermovision camera after a single treatment with both cryogenic liquids, was higher in the case of carbon dioxide[17]. In the scientific literature, information is also provided on other risks associated with the use of liquid nitrogen during treatment[12,15]. This gas is not poisonous, but its volatilisation into the atmosphere lowers oxygen con-

tent and may lead to hypoxia or even fainting[12,15]. Another danger that may arise when using this coolant is the risk of explosion due to the condensation of oxygen on small, leaky metal parts of the cryostimulation device[12]. In order to avoid such a situation, it is extremely important to properly train medical personnel and to inspect the equipment annually, which guarantees the durability and safe operation of this device[15]. To the best of our knowledge, there is no information available in the literature on the risks associated with the use of carbon dioxide.

As previously noted, in comparison to carbon dioxide, liquid nitrogen cools the tip of the cryo-applicator down to a lower temperature. However, a review of available research allows to note that the duration of both treatments should be the same and used daily for 2 weeks (10 treatment sessions) [12,14,17,18,19,20,21]. Therefore, the duration of treatments and their number should not be factors influencing the cost of treatment.

A comparison of the prices of both coolers shows that they differ depending on the supplier. One of the available offers shows that 1 kg of nitrogen costs PLN 5.80, while 1 kg of carbon dioxide costs PLN 4.30[22,23]. Taking specifications of the devices from different companies into account, it was noted that the use of liquid nitrogen is slightly greater than that of carbon dioxide. The above data may allow to suggest that usage of the latter cryogenic liquid is less expensive[12,24]. The purchase of both coolants is not problematic because they are available in the catalogues of delivery companies[22,23,25]. In 2004, the benefit package of the National Health Fund (NFZ) included cryotherapy with both cryogenic liquids[26]. Currently, only the treatment with liquid nitrogen is reimbursed[27], which may result in its more frequent use at rehabilitation offices.

In the available literature, it is shown that effective treatment with low temperatures depends, *inter alia*, on the type of cooling substance used and the temperature to which it is cooled[15]. So far, the effectiveness of this therapy has been demonstrated to reduce pain in various disease entities[14], such as painful shoulder syndrome[20,28,29], previous total knee replacement surgery[30] or ankylosing arthritis[18,19,31]. However, there are few studies in which the effectiveness of cryostimulation treatments would be compared using different cryogenic liquids, i.e. nitrogen and carbon dioxide. Therefore, in this study, the effectiveness of 2 different coolants in the course of LBPS was assessed.

STUDY AIM

The aim of the study was to control the treatment process of 2 cryostimulation treatments, i.e. with the use of carbon dioxide and liquid nitrogen in the course of LBPS.

Therefore, the following research questions were posed:

1. Which of the cryostimulation treatments is more effective in terms of centralising pain symptoms, reducing their intensity and improving their qualitative aspects?
2. Is there a difference in disability level reduction between carbon dioxide and nitrogen cryostimulation?
3. Does one of the local cryostimulation treatments more effectively improve the emotional state of patients and self-efficacy related to pain?

MATERIALS AND METHODS

The study, which included 60 patients complaining of discopathic LBPS, was carried out between 2018-2019 at one of the rehabilitation clinics in Kraków. The patients were qualified by a specialist in medical rehabilitation, based on an interview, physical examination and analysis of imaging examinations. The inclusion criteria included: chronic LBPS due to discopathy (according to ICD-10: code M54), lasting over 3 months, according to the Quebec Task Force[32] classification. The exclusion criteria included: the patient's condition requiring surgery, co-existence of advanced neurological, rheumatic, urological and/or psychiatric disorders, and the patient's unsystematic participation in the therapy. Then, the patients were randomly divided into 2 groups. One group (G1) was treated with carbon dioxide, while the other (G2) was subjected to treatment with liquid nitrogen. In the G1 group, the mean age value was 62.7 ± 15.3 years, and in G2, 56.2 ± 13.3 years. In G1, the patients experienced the analysed pains 8.1 ± 4.3 months, on average, and in G2, 7.2 ± 3.1 months. Women accounted for 67% of G1 group and 57% of G2 group. A detailed description of the study groups is presented in Table 1.

All of the respondents underwent cryotherapy in the area of the lumbosacral spine (LS). Treatments were

Table 1

Patients' characteristics before treatment		
Categories	**G1**	**G2**
Number of patients (n)	30	30
Age (years)	62.7±15.3	56.2±13.3
Duration of symptoms (months)	8.1±4.3	7.2±3.1
Sex (%):		
• Female	67	57
• Male	33	43
Place of residence (%):		
• City	97	87
• Country	3	13
Professional activity (%):		
• Working	57	67
• Pensioner	43	33
Level of education (%):		
• Higher	43	47
• Secondary	53	53
• Post-secondary	3	0

performed daily on weekdays for 2 weeks, thus, in total, each patient participated in 10 sessions. Before each therapy session, the continuity, colour and moisture of the patients' skin in the area treated was checked and, if necessary, it was dried. Such action ensures safety during cryostimulation and prevents potential frostbite[12]. The duration of each treatment was 3 minutes at a time. During its implementation, the physiotherapist, holding the blowing nozzle in protective gloves, made circular movements so that its outlet was approximately 20 cm from the treated area[12]. For cryotherapy with carbon dioxide, the CyroFlex device, a Cyro-T (NR-2) portable model was used, while the treatment with liquid nitrogen was performed with the Kriopol R device from Kriomedpol. During this therapy, the patient did not undergo any other forms of treatment.

The research tool was a questionnaire consisting of 2 parts. In the first part, participants answered 5 closed questions concerning age, sex, place of residence, professional activity, level of education and the duration of the episode. The second part, on the other hand, included questionnaires allowing to analyse the following variables:

- Centralisation of symptoms – based on the topography of distal symptoms before and after therapy, using Pain Drawing[33].
- The intensity of the perceived pain – using the Visual Analogue Scale[34].
- Level of pain-related disability using the Roland Morris Disability Questionnaire (RMQ)[35].
- Qualitative aspects of pain - using the indicators of the McGill Pain Questionnaire (MPQ)[36].
- The patient's emotional state, in terms of level of fear, joy and anger; for this purpose, the Adjectival Scale for the Study of Emotions (SE-T Scale) was used[37].
- d Self-efficacy concerning pain level using the Pain Self-Efficacy Questionnaire (PSEQ)[38].

Additionally, before being included in the study, all respondents gave their consent for participation and were informed about its purpose, course and anonymity. In order to obtain answers to the research questions posed, appropriate statistical analysis was conducted. The Student's *t*-test was used for dependent and independent samples, assuming the level of statistical significance equal to 0.05.

RESULTS

Prior to therapy, a greater percentage of patients experienced distal symptoms in the lower leg and foot in the G1 group (foot: 13%, lower leg: 30%) compared to the G2 group (foot: 3%, lower leg: 23%). A similar percentage of patients complained of pain in more proximal parts of the body (Table 2).

There were no statistically significant differences in many of the remaining variables before starting therapy. Only the group treated with nitrogen obtained statistically significantly higher values of such indicators in the McGill Pain Questionnaire, such as: WOB: S, WOB: OC and LS than the group treated with carbon dioxide. The G2 group was also characterised by a significantly higher level of anxiety and anger compared to the G1 group (Table 3).

After the therapy, all the studied variables improved. The analysis of the most distal symptoms showed that in both groups, they had centralised or even subsided. In the G1 group, 23% of patients did not experience any symptoms or they were located only in the spine, and in the G2 group - 36%. On the other hand, a few patients still reported pain symptoms in the lower leg (3% in each group), while for no one was pain indicated in the foot. It is difficult to say whether the above change differed statistically significantly in both groups, the more so that in the G2 group, a greater percentage of patients did not experience symptoms in the parts of the body most distant from the spine before treatment (Table 2). Statistical analysis of subsequent variables showed significant improvement in all variables before and after therapy in both study groups. The intensity of perceived pain decreased significantly by 3.2 points in G1, and by 3.3 points in G2. The level of disability significantly decreased by 5.0 points in G1 and by 4.6 points in G2. Also, in both study groups, as a result of treatment, all indicators of the McGill Pain Questionnaire improved, the level of anxiety (in G1: by 10.3 points, and in G2: by 16.8 points) and anger (G1 by 15.4 points, G2 by 10.3 points). Regardless of the cryogenic fluid used, the levels of joy (in G1: by -12.8 points, G2: by -16.7 points) and pain self-efficacy also improved (in G1: by -8.0 points, G2: by -11.0 points) (Table 4).

On the basis of the Student's *t*-test, no statistically significant differences were found: between the changes obtained as a result of treatment in either study group with regard to pain and disability levels, the majority of indicators for the McGill Pain Questionnaire, and pain-related self-efficacy. A statistically significant difference between the groups was noted only in the case of the WOB index: OC ($p = 0.0047$) and the level of neg-

Table 2

Percentage of patients from groups G1 and G2 experiencing distal symptoms in the analysed body parts before and after therapy

Localisation of distal symptoms [%]	Before treatment		After treatment	
	G1	G2	G1	G2
No complaints	0%	0%	10%	3%
Spine	0%	0%	13%	33%
Hip	23%	17%	33%	27%
Buttock	10%	23%	23%	20%
Thigh	23%	33%	17%	13%
Shank	30%	23%	3%	3%
Foot	13%	3%	0%	0%

Table 3

Comparison of groups before therapy in terms of the analysed variables

Variables before therapy	G1		G2		t	*p*
	x	*SD*	x	*SD*		
Pain intensity	6.0	1.9	6.5	1.5	-0.9623	0.3399
Disability Level	12.7	7.1	11.2	4.3	1.0317	0.3065
Pain-related efficacy	45.3	13.6	39.5	12.5	1.7231	0.0902
McGill: WOB:S	13.0	4.9	16.3	5.5	-2.4017	0.0195*
McGill: WOB:A	2.4	2.1	3.0	2.5	-1.0111	0.3161
McGill: WOB:OC	2.3	1.1	2.9	1.3	-2.0314	0.0468*
McGill: WOB:R(S)	2.9	1.3	3.0	1.4	-0.4678	0.6417
McGill: WOB:R(AOC)	2.1	1.6	2.3	1.6	-0.6498	0.5184
McGill: WOB:R(O)	4.9	2.3	5.4	2.7	-0.6729	0.5037
McGill: WOB:(O)	27.5	10.1	32.9	12.5	-1.8536	0.0689
McGill: LWS	12.6	2.8	14.1	2.5	-2.2389	0.0290*
Emotion level: anxiety	17.0	9.6	27.4	12.1	-3.6904	0.0005*
Emotion level: joy	14.9	6.7	11.5	6.7	1.9702	0.0536
Emotion level: anger	7.8	6.2	15.4	8.1	-4.0587	0.0001*

* – statistically significant result

ative emotions (anxiety: $p = 0.0132$, anger: $p = 0.0030$). The group treated with nitrogen demonstrated greater improvement for these variables compared to the group treated with carbon dioxide. It should be noted, however, that the baseline levels of the WOB index in G2 were higher: OC, anger and anxiety, thus, it was easier to obtain better results for these variables (Table 5).

DISCUSSION

Based on the results of the author's work, it was primarily observed that both groups treated using cryotherapy, with the use of various cooling gases, achieved similar improvement in most of the analysed variables.

One of the aspects studied was the centralisation of symptoms, analysed on the basis of topography regarding the most distal symptoms marked before and after therapy[33]. Centralisation is a phenomenon determining the correct behaviour of symptoms as a result of treatment. It is where the pain that radiates to the distal parts of the limbs, 'receding' to the spine, as a result of the treatment. The centralisation of symptoms plays a crucial role in the diagnosis and evaluation of treatment effectiveness[33,39]. Analysing the results of our work on the centralisation of pain, it can be concluded that improved was noted in both groups. After the therapy, there were people who did not feel any pain (G1: 10%, G2: 3%). The percentage of patients experiencing distal symptoms in the thigh, lower leg and foot also decreased. The symptoms centralised to the hip (G1: 33%, G2: 27%) and spine (G1: 13%, G2: 33%). The above results prove the effectiveness of both sources of cold-application in this variable. Currently, there are no studies in which the effectiveness would be assessed of local cryotherapy, based on the centralisation of symptoms in LBPS. A review of the available literature allows to state that the significance of this phenomenon in the course of LBPS has been analysed in several studies[40,41,42]. The phenomenon of centralisation was also observed in a study analysing the effectiveness of laser therapy among patients with LBPS. The obtained results showed that a comprehensive rehabilitation programme, including TENS currents, magnetic fields, thermotherapy and kinesiotherapy, regardless of whether it was combined with laser therapy or not, caused similar changes in the localisation of symptoms[39].

Another variable assessed in this study was the level of pain. Based on the obtained results, it was found that the pain intensity decreased in both study groups, but it was not shown that one of the cryotherapy types was more effective than the other in this respect ($p = 0.7862$). The above results are consistent with the those achieved in studies by other authors[21,43,44,45]. Demulin et al.[43] demonstrated the effect of cryotherapy with carbon dioxide on the reduction of pain intensity in patients following knee reconstruction. Woźny et al.[21] noted that a local cryotherapy procedure, combined with McKenzie exercises, significantly reduces the intensity of chronic pain while increasing range of motion in the lumbar spine. However, the authors of this study did not specify exactly what type of cryotherapy was used in the treatment[21]. Straburzyńska-Lupa et al.[44] compared the effects of single, 3-minute treatments, one of which consisted of directing cold air (-30°C), and the other vapour of liquid nitrogen (-150 C) to the knee joints of women with rheumatoid arthritis. In both groups, a statistically significant reduction of perceived pain was achieved, and no significant differences were found between the groups. Nugrah et al[45], who inves-

Table 4

Changes obtained separately for both treatment groups

Group	Categories	Measurement I		Measurement II		Difference	*t*	*p*
		x	*SD*	x	*SD*			
G1	Pain intensity	6.0	1.9	2.8	1.7	3.2	13.24	< 0.0001*
G2	Pain intensity	6.5	1.5	3.2	2.1	3.3	11.95	< 0.0001*
G1	Disability level	12.7	7.1	7.7	5.9	5.0	7.7500	< 0.0001*
G2	Disability level	11.2	4.3	6.6	5.0	4.6	9.8124	< 0.0001*
G1	Pain-related efficacy	45.3	13.6	53.3	7.7	-8.0	-6.0958	< 0.0001*
G2	Pain-related efficacy	39.5	12.5	50.5	11.2	-11.0	-6.9149	< 0.0001*
G1	McGill: WOB:S	13.0	4.9	5.2	3.4	7.8	8.1098	< 0.0001*
G2	McGill: WOB:S	16.3	5.5	7.4	5.6	8.9	9.5811	< 0.0001*
G1	McGill: WOB:A	2.4	2.1	0.4	0.7	2.0	5.9104	< 0.0001*
G2	McGill: WOB:A	3.0	2.5	0.7	1.6	2.3	5.3633	< 0.0001*
G1	McGill: WOB:OC	2.3	1.1	1.2	0.8	1.0	6.0999	< 0.0001*
G2	McGill: WOB:OC	2.9	1.3	1.0	0.9	1.9	7.8706	< 0.0001*
G1	McGill: WOB:R(S)	2.9	1.3	1.4	0.9	1.5	8.1459	< 0.0001*
G2	McGill: WOB:R(S)	3.0	1.4	1.1	1.3	1.9	7.1356	< 0.0001*
G1	McGill: WOB:R(AOC)	2.1	1.6	0.6	0.9	1.4	5.1509	< 0.0001*
G2	McGill: WOB:R(AOC)	2.3	1.6	0.8	1.0	1.6	4.9438	< 0.0001*
G1	McGill: WOB:R(O)	4.9	2.3	2.0	1.4	2.9	8.3306	< 0.0001*
G2	McGill: WOB:R(O)	5.4	2.7	1.9	2.2	3.5	6.3597	< 0.0001*
G1	McGill: WOB:(O)	27.5	10.1	11.0	6.9	16.5	9.8378	< 0.0001*
G2	McGill: WOB:(O)	32.9	12.5	12.8	11.7	20.1	8.6960	< 0.0001*
G1	McGill: LWS	12.6	2.8	7.2	3.9	5.4	8.8054	< 0.0001*
G2	McGill: LWS	14.1	2.5	8.0	4.4	6.1	8.0947	< 0.0001*
G1	Emotion level: anxiety	17.0	9.6	6.7	6.2	10.3	7.3691	< 0.0001*
G2	Emotion level: anxiety	27.4	12.1	10.6	11.0	16.8	7.9812	< 0.0001*
G1	Emotion level: joy	14.9	6.7	27.6	4.9	-12.8	-9.6990	< 0.0001*
G2	Emotion level: joy	11.5	6.7	28.2	8.5	-16.7	-9.7121	< 0.0001*
G1	Emotion level: anger	7.8	6.2	2.4	3.3	5.4	6.2987	< 0.0001*
G2	Emotion level: anger	15.4	8.1	5.0	6.9	10.3	7.7853	< 0.0001*

* – statistically significant result

tigated the effect of a cryochamber on the level of pain in patients with LBPS, observed a similar reduction in the intensity of pain symptoms, regardless of the applied, i.e. lower (-67°C) and higher (-5°C) temperatures. The above-cited studies[44,45] and the results of our own work allow to suggest that regardless the temperature of the substance used to cool the body surface, a similar analgesic therapeutic effect can be obtained.

The Roland-Morris Disability Questionnaire is the recommended tool for examining the disability level in LBPS[46]. In the authors' study, as a result of the implemented therapies, disability decreased significantly in both groups and neither of the 2 analysed cryotherapy treatments turned out to be more effective than the other ($p = 0.5906$). Nugraha et al.[45] demonstrated improvement in the functioning of patients with LBPS after the use of a cryochamber. Jastrząbek et al.[47] observed a similar degree of improvement in activity among patients with rheumatoid arthritis, regardless of the cooling agent used, i.e. liquid nitrogen and cold air.

Pain is the most common symptom in clinical practice. It is complex, multidimensional in nature, made up of biological and psychological mechanisms. It provides valuable diagnostic and therapeutic information during treatment. Therefore, the method of pain assessment is very important[48]. In the author's own work, the qualitative aspects of pain, i.e. sensory and emotional, were examined using appropriate indicators of the McGill Pain Questionnaire[48,49]. On the basis of the obtained results, it was observed that both types of cryostimulation improved the majority of the analysed indicators. Statistical analysis showed that only in the case of the WOB: OC index, the treatment with liquid nitrogen turned out to be more effective ($p = 0.0047$). It should be emphasized that patients from G2 started with a higher level of this index prior to therapy, therefore, it was easier for them to obtain better results compared to G1. Dehghan and Farahbod[50] used the McGill

Table 5

Comparison of therapy-related effects between groups

Change as a result of therapy	G1		G2		*t*	*p*
	x	*SD*	x	*SD*		
Pain intensity	3.2	1.3	3.3	1.5	-0.2726	0.7862
Disability level	5.0	3.6	4.6	2.6	0.5410	0.5906
Pain-related efficacy	8.0	7.2	11.0	8.7	-1.4497	0.1525
McGill: WOB:S	7.8	5.3	8.9	5.1	-0.8227	0.4141
McGill: WOB:A	2.0	1.9	2.3	2.4	-0.5409	0.5907
McGill: WOB:OC	1.0	0.9	1.9	1.3	-2.9387	0.0047*
McGill: WOB:R(S)	1.5	1.0	1.9	1.5	-1.3228	0.1911
McGill: WOB:R(AOC)	1.4	1.5	1.6	1.7	-0.3162	0.7530
McGill: WOB:R(O)	2.9	1.9	3.5	3.0	-0.8673	0.3893
McGill: WOB:(O)	16.5	9.2	20.1	12.7	-1.2834	0.2044
McGill: LWS	5.4	3.4	6.1	4.2	-0.7523	0.4549
Emotion level: anxiety	10.3	7.7	16.8	11.5	-2.5568	0.0132*
Emotion level: joy	12.8	7.2	16.7	9.4	-1.8164	0.0745
Emotion level: anger	5.4	4.7	10.3	7.3	-3.0955	0.0030*

* - statistically significant result

Pain Questionnaire to compare the effectiveness of cryotherapy, thermotherapy and pharmacotherapy, providing an analgesic effect among patients experiencing acute LBPS. The obtained results allowed to conclude that the application of local cryotherapy treatments, with the use of ice and heat compresses, turned out to be more effective than treatment with naproxen.

Brain-imaging studies showed that acute and sub-acute pain conditions only stimulate pain-related areas. On the other hand, chronic pain conditions affect changes in the structure and functioning of this organ and activate the part responsible for emotions[51]. Available studies allow to confirm that depressive mood, stress or anger, influence the development of chronic LBPS[52,53,54]. Therefore, the analysis of therapeutic effectiveness in terms of psychological factors, is very advisable[52]. In the authors' work, the influence of 2 types of cryotherapy on the level of positive (joy) and negative emotions (anger and fear) was examined. Both treatments improved all emotions. Statistical analysis indicated that nitrogen treatment reduced anxiety ($p = 0.0132$) and anger ($p = 0.0030$) to a greater extent than with carbon dioxide. It should be noted, however, that patients in G2 also started with a higher level of these 2 types of emotions and therefore, it was easier for them to obtain better results. Rymaszewska et al.[55] investigated the effect of whole-body cryotherapy in patients with depression and anxiety disorders. During the study, patients received standard pharmacotherapy prescribed by psychiatrists. Researchers found that the cryochamber relieved selected psychosomatic symptoms, reduced pain and regulated biological rhythms often disturbed during psychiatric illnesses. The authors suggest that in the treatment of emotional disorders, the use of exposure to cold could be applied as adjuvant therapy. However, this is an issue that requires confirmation in further, more extensive and randomised control studies.

The last analysed aspect in the authors' work was pain-related self-efficacy. A review of literature on the subject allows to confirm a correlation between the level of this variable and the intensity of pain as well as disability in the acute and chronic period of LBPS[56,57]. Therefore, it should be taken into account when analysing the effectiveness of various therapeutic methods in the course of these disorders[58]. In the available studies, it has been shown that cognitive behavioural therapy improves pain-related self-efficacy in LBPS[59,60]. The above results are similar to those obtained by the authors of this work. As a result of the therapy, both groups achieved statistically significant improvement for this variable. However, neither of these treatments was more effective ($p = 0.1525$).

In conclusion, it can be stated that both cryotherapy treatments improve the condition of patients complaining of chronic LBPS. However, the obtained results do not allow to show which type of cooling source has greater therapeutic efficacy. Therefore, research should be continued to analyse the long-term effects of cryotherapy for pain syndromes in the musculoskeletal system.

In this study, to determine the effectiveness of treatments with carbon dioxide and liquid nitrogen, only subjective measures were used to examine variables such as: symptom centralisation, pain level, disability and pain-related self-efficacy, as well as the qualitative aspects of pain and the emotional state of the patient. Therefore, no physical examinations were performed, including the assessment of, for example, muscle tone, sensitivity to pressure or mobility of the lumbar spine. Also, no follow-up measures were conducted. Therefore, the above

elements of the methodology should be taken into account in subsequent studies taking up these research issues.

CONCLUSIONS

1. Both analysed treatments are similarly effective in terms of such variables as: centralisation of symptoms, level of pain intensity, disability, joy and pain-related self-efficacy, as well as most of the analysed MPQ indicators.
2. Cryostimulation with liquid nitrogen may be more effective only in improving the WOB index: OC of the MPQ questionnaire and the level of anger and anxiety, but the obtained results do not allow for definitive confirmation of these results.
3. The use of both cryostimulation treatments may support the treatment of LBPS.

Conflict of interests
None declared

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