THE EFFECT OF WHOLE-BODY CRYOTHERAPY ON THE LIPID PROFILE AND BLOOD GLUCOSE CONCENTRATION IN OLDER WOMEN

WPŁYW KRIOTERAPII OGÓLNOUSTROJOWEJ NA PROFIL LIPIDOWY I STĘŻENIE GLUKOZY WE KRWI U KOBIET W STARSZYM WIEKU

Anna Misiorek[1], Aleksandra Kulis[1]*, Jacek Głodzik[2], Krzysztof Wrześniewski[3], Anna Marchewka[4]

[1] Akademia Wychowania Fizycznego w Krakowie, Wydział Rehabilitacji Ruchowej, Katedra Terapii Zajęciowej, 31-571 Kraków, al. Jana Pawła II 78

[2] Akademia Wychowania Fizycznego w Krakowie, Wydział Rehabilitacji Ruchowej, Katedra Fizjoterapii, 31-571 Kraków, al. Jana Pawła II 78

[3] Akademia Wychowania Fizycznego w Krakowie, Wydział Rehabilitacji Ruchowej, Instytut Nauk Społecznych, 31-571 Kraków, al. Jana Pawła II 78

[4] Akademia Wychowania Fizycznego w Krakowie, Wydział Rehabilitacji Ruchowej, Katedra Rehabilitacji Klinicznej, 31-571 Kraków, al. Jana Pawła II 78

*e-mail: aleksandra.kulis@awf.krakow.pl

ABSTRACT

The aim of the study was to evaluate changes in the level of total cholesterol, HDL, LDL, triglycerides, and glucose in older women with spondyloarthrosis, who underwent whole-body cryotherapy treatments. The experimental group, which comprised 69 older women between 65 and 70 years of age, was randomly divided into three subgroups. Each subgroup was exposed to different physiotherapeutic procedure for two weeks: cryotherapy, kinesiotherapy, and cryotherapy combined with kinesiotherapy. The control group comprised 25 women who did not get any therapeutic intervention. The level of total cholesterol, LDL fraction, HDL fraction, triglycerides, and glucose was assessed for each group. No significant changes in any of the studied parameters of fat fractions were observed. In women exposed to both cryotherapy and kinesiotherapy, the level of fasting glycemia decreased significantly. Applying whole-body cryotherapy to older women with spondyloarthrosis does not cause changes in the level of cholesterol and triglycerides, but may cause changes in the level of glucose.

Keywords: whole-body cryotherapy, total cholesterol, LDL-cholesterol, HDL-cholesterol, triglycerides, glucose

STRESZCZENIE

Celem pracy była ocena zmian poziomu cholesterolu całkowitego, frakcji HDL i LDL, trójglicerydów i glukozy u starszych kobiet ze zmianami zwyrodnieniowymi kręgosłupa lędźwiowego, poddanych krioterapii ogólnoustrojowej. Grupa badanych złożona z 69 kobiet pomiędzy 65 a 70 rokiem życia, została losowo podzielona na trzy

grupy, z których każda poddana została innemu rodzajowi terapii: krioterapii, krioterapii połączonej z kinezyterapią, tylko kinezyterapii. Grupę kontrolną stanowiło 25 kobiet, niepoddanych żadnej interwencji terapeutycznej. Poziomy cholesterolu całkowitego, LDL, HDL, trójglicerydów i glukozy na czczo zostały oznaczone w każdej grupie. Badane wskaźniki frakcji tłuszczowych nie uległy istotnym zmianom w żadnej z grup. U kobiet poddanych zarówno krioterapii, jak i kinezyterapii poziom glikemii na czczo znacząco się obniżył. Zastosowanie krioterapii ogólnoustrojowej nie wpływa na stężenie cholesterolu i trójglicerydów u starszych kobiet, lecz może wywołać zmiany poziomu glukozy.

Słowa kluczowe: krioterapia ogólnoustrojowa, cholesterol całkowity, LDL-cholesterol, HDL-cholesterol, trójglicerydy, glukoza

1. Introduction

Cryotherapy uses the stimulating effect of extremely low temperatures (below −100 ºC) applied to the body for three minutes [1, 2]. According to the methodology of its application, cryotherapy should be followed immediately by kinesiotherapy [3], especially when used as a form of treatment of patients, not as a biological restitution. Kinesiotherapy should be understood as movement therapy with the aim of exercising the joints that were previously cooled. In Poland, after whole body cryotherapy people bicycle or exercise the whole body for about 20–30 minutes. Such methodology is used, because after cryotherapy the patient is able to exercise more effectively and with less pain. Cryotherapy is indicated for people who suffer from joint or muscle lesions, pain or as an element of biological renewal [3, 4 ,5, 6, 7, 8]. Even though this method is quite popular, there are still few studies investigating its effect on the human body. In particular, there are not so many reports on the effect of cryotherapy on the body of older people, who because of suffering from osteoarthritis or rheumatoid arthritis, use this method frequently, even though old age is listed as a relative contraindication for cryotherapy treatments, due to the fact that seniors often suffer from serious disorders of the heart, circulatory system and hematopoietic system.

Numerous epidemiological studies have confirmed the frequent occurrence of hypercholesterolemia in elderly [9, 10, 11, 12, 13, 14]. Old age also has an established negative role in the development of atherosclerosis, which is considered as the leading cause of death in the world [15]. The occurrence of hyperglycemia and impaired glucose tolerance in older people increases with age. More than 22% of people aged between 65 and 74 years have been diagnosed with glucose tolerance disorders, and over 18% of people from this age group suffer from diabetes. Diabetes leads to serious complications in various systems and organs, e.g. blindness, complications of the circulatory system, and kidney failure. Many of these people react well to the recommended diet and physical activity, and do not require pharmacological treatment [16, 17].

The authors of scientific publications on cryotherapy [1, 6, 7, 18, 19, 20, 21, 22, 23] follow different methodologies: some researchers use cryotherapy as the only method, while others use it in combination with kinesiotherapy, with different duration and intensity. Furthermore, cryotherapy is used among athletes either between training sessions or after a single intense training session. Different methodologies not allow to make consistent conclusions concerning the effectiveness of the method, which may be different depending on both personal factors (related to age, underlying disease, comorbidities, medicine taken, physical activity, etc.) and external factors (treatment duration, number of treatments in a series, duration and type of kinesiotherapy performed after cryotherapy, application of cryotherapy before or after physical training, etc.) Cryotherapy may cause different reactions in heterogeneous groups of patients. This is why experimental groups should be selected more precisely, first and foremost, in terms of the underlying disease and comorbidities. Furthermore, the patient's age should be taken into consideration and, if possible, the evaluation of the results should include the additional effect of increased physical activity, which usually follows whole-body cryotherapy treatment. Due to the above conclusions, the study distinguished three experimental groups (in order to obtain clear information about the effect of each component of treatment combining cryotherapy and kinesiotherapy on the body), which comprised persons distribution homogenous in terms of sex, age, and illness, i.e., osteoarthritis, because people who suffer from it frequently use cryotherapy.

Two publications that confirm the beneficial effect of 10 cryotherapy sessions on the lipid profile of young men [6, 24] and one publication confirming the beneficial effect of a half-year training including 20 cryotherapy sessions on the lipid profile of obese individuals 40 years of age have been found [19]. Concentrations of total and LDL cholesterol decreased in males, who underwent 10 sessions of cryotherapy combined with 30 minutes of physical exercises [25]. There are no reports about the effect of cryotherapy on the lipid profile and glucose level in the blood of older women. The effect of cryotherapy highly depends on response of organism to stimulation with cold what is dependent on age, gender, anthropometric characteristics, fat mass or health condition, fitness level etc. [26, 27]. It can be assumed that cryotherapy combined with kinesiotherapy will have a greater effect on persons undergoing this treatment than cryotherapy or kinesiotherapy standalone and even, if 10 sessions of cryotherapy alone may have limited impact on lipid profile or level of blood glucose, adding kinesiotherapy to it may make a difference. As there is lack of protocols, which combine cryotherapy with exercises in older women, the number of sessions that was used in this research was 10, which seemed to be the minimal dosage that could be effective, especially, if combined with kinesiotherapy.

The aim of this paper was to investigate, whether a two-week series of whole-body cryotherapy treatments, kinesiotherapy, and cryotherapy combined with kinesiotherapy affects the level of fat fractions and blood glucose in women between 65 and 70 years of age, who underwent cryotherapy treatment due to lumbar spondylarthrosis

2. Materials and methods

The study encompassed 69 women living in an urban environment (Krakow), who were treated on an outpatient basis due to the chronic lower back pain caused by spondylarthrosis. The participants, who met the qualification criteria, were selected among the women who volunteered for the project after reading the poster promoting the study. The treatment of the patients took place over two weeks, starting Monday through Friday (10 business days). The inclusion criteria for the study were as follows: age between 65 and 70 years, baseline intensity of pain up to 5 points on a 10-point Visual Analogue Scale (VAS) (where 0 denotes the lack of pain, and 10 denotes unbearable pain), diagnosis of lumbar spondylarthrosis confirmed by imaging documentation (X-ray, CT, and/or MRI). Each patient was informed about the study and gave consent to participate. The exclusion criteria for the study were as follows: exacerbation of the illness (acute pain greater than 5 points on the VAS), other serious illnesses of the musculoskeletal system, chronic inflammatory diseases, and the occurrence of the illnesses that constitute a contraindication for whole-body cryotherapy treatments (for instance, Raynaud's disease, neuropathies of the sympathetic nervous system, hypothyroidism with no intake of hormonal medicine, considerable anemia, varicose veins, inflammatory and thrombotic conditions of the veins, neoplasm, serious diseases of the heart and the circulatory system, acute and chronic illnesses of the respiratory system, etc.).

The control group (I) comprised 25 older women aged between 65 and 70 years who suffered from spondylarthrosis and were not given any therapeutic procedures (neither kinesiotherapy nor cryotherapy).

Due to the methodology of using this treatment in older people with illnesses (which involved combining cryotherapy and kinesiotherapy), the experimental group was randomly divided into three groups to identify the effect of each of these methods. The second group (II, "Cryo") comprised 22 persons undergoing whole-body cryotherapy, the third group (III, "PT") comprised 23 persons undergoing kinesiotherapy, and the fourth group (IV, "PT+Cryo") comprised 24 persons undergoing both whole-body cryotherapy and kinesiotherapy.

The mean BMI values in each of the groups were similar and equal 27,24 in the second group, 27,09 in the third group, and 28,15 in the fourth group. None of the participants smoked cigarettes, suffered from diabetes or took drugs for hypercholesterolemia.

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2.1. Biochemical analysis

One resting blood sample of 5 ml was collected in the control group and two resting blood samples (before and after two weeks of treatment) were collected from each person in experimental group. The blood was collected by a qualified nurse, on an empty stomach, from the antecubital forearm vein, after a 10-minute rest period and in a sitting position using evacuated tubes. The first blood sample was collected two days before the treatment, and the second sample was collected a day after the end of the treatment. The serum were isolated within 1 h and stored at 70 °C until assay. The measurement of total cholesterol (TCh), HDL and triglycerides was conducted in a certified Synevo laboratory in Krakow, with the use of spectrophotometry performed with a Cobas 8000 analyzer. The measurements of the LDL fraction were taken using a direct method, i.e., spectrophotometry, performed with a Cobas 6000 analyzer. The level of glucose was measured in the Laboratory of Traumatology of the Musculoskeletal System at the University of Physical Education in Krakow with a glucometer Optimum Xido (by Abbott) for monitoring glucose concentration in whole fresh blood.

2.2. Therapy sessions

Each person in each group was exposed to treatments according to group placement. Therapy was performed every day, five days a week, for a period of two weeks.

Cryotherapy treatments were conducted in JUKA cryochamber (manufactured in 2005, Model 0401), using liquid nitrogen. The temperature in the pre-chamber during treatment was −60 ºC, and in the main chamber, the temperature was −120 ºC. Firstly, women entered the pre-chamber for 30 seconds, and then they entered the main chamber for 3 minutes. As per the guidelines, the persons undergoing treatment in the cryochamber were dressed in two-piece swimsuits. Body parts that were the most exposed to the effect of low temperatures were covered with protective clothing: hands were protected with gloves, ankles and knee pits with long socks, feet with wooden clogs, auricles with a headband or a cap, and face with a surgical mask with a lining made from double gauze.

Kinesiotherapy was carried out in groups of 5–12 persons. It began with a 5-minute warm-up, and was followed by a 20–25-minute main session and a 5–10-minute cool-down. The relaxation portion was expanded with balance exercises recommended for persons from this age group. Kinesiotherapy was always conducted in the same room and by the same physiotherapist. The aim of the exercises was to strengthen and increase the flexibility of the muscles of the trunk, lower limbs, and upper limbs. The intensity of the exercises was adjusted in accordance with the recommendations of the US Centers for Disease Control and Prevention.

2.3 Statistical analysis

The normality of distribution of the studied variables was tested with the Shapiro-Wilk test. According to the results of this test, the studied variables showed a distribution close to normal. Therefore, it was decided to use two versions of the General Linear Model (GLM) for further analysis: 1) for one variable, and 2) for repeated measurements (2x3 model, Time x Group). When the sphericity of a studied variable was not indicated (Mauchly's test), the results of the GLM analysis were subjected to Greenhouse-Geisser correction. Furthermore, when the analysis revealed statistically significant differences between the groups, the Bonferroni post-hoc test, was used. The GLM was used instead of Student's T-test, to determine whether the applied therapeutic method had a considerable effect on changes in the studied biochemical parameters (Time x Group).

3. Results

Table 1 shows the results of selected blood parameters before and after the applied therapeutic methods, compared to the control group and norms.

There were no significant between-group differences for any of the lipid or glucose variables (see Table 1). In each of the groups, the TCh was either at the upper limit of the norm (Group III) or slightly exceeded it (Groups I, II, and IV). The level of the LDL fraction was slightly exceeded in all groups, while the levels of HDL and triglycerides were within the norm range.

The results of the GLM analysis did not reveal statistically significant ($p > 0.05$) changes in the observed endpoint values of the studied lipid indices (Time). The study also did not reveal any changes in these parameters ($p > 0.05$) due to the applied therapeutic method (Time x Group).

Table 1. Changes in the concentration of lipids and glucose in response to different therapies (mean value ± standard deviation)

	Before treatment				**After treatment**			**Norm**
Group	I	II	III	IV	II'	III'	IV'	
Total cholesterol (mg/dL)	199.2±39.4 Cv = 0.198	190.4±36.5 Cv = 0.191	187.8±27.0 Cv = 0.144	195.8±35.0 Cv = 0.179	182.8±31.2 Cv = 0.171	191.1±27.0 Cv = 0.141	195.8±35.0 Cv = 0.179	<190
HDL cholesterol (mg/dL)	53.6±14.1 Cv = 0.263	58.2±17.1 Cv = 0.294	53±16.0 Cv = 0.302	52.3±12.2 Cv = 0.233	56.2±13.4 Cv = 0.238	54±14.0 Cv = 0.259	53.1±12.1 Cv = 0.228	>45
LDL cholesterol (mg/dL)	126.1±39.6 Cv = 0.314	117.9±29.6 Cv = 0.251	118.6±28.3 Cv = 0.239	125.9±34.9 Cv = 0.313	111.9±28.1 Cv = 0.251	123±30.0 Cv = 0.244	118.8±35.0 Cv = 0.295	<115
Triglicerydes (mg/dL)	129.9±63.4 Cv = 0.488	108.1±46.0 Cv = 0.425	114.7±36.1 Cv = 0.315	124.8±52.0 Cv = 0.417	105.4±41.0 Cv = 0.389	107.2±36.0 Cv = 0.336	120.4±56.2 Cv = 0.467	<150
Glukose (mg/dL)	103.7±23.5 Cv = 0.227	103±24.0 Cv = 0.233	108.2±19.1 Cv = 0.176	99±12.1 Cv = 0.122	92.5±30.1 Cv = 0.325	104.3±23.8 Cv = 0.228	81.8±16.9** Cv = 0.207	<100

Cv – coefficient of variation
* pretest-postest difference is statistically significant at the 0.05 level
** pretest-postest difference is statistically significant at the 0.01 level

In the case of glucose concentration in the blood, the study also did not prove statistically significant differences between the groups in the first measurement ($p > 0.05$). In Group II ("Cryo") and Group III ("PT") the fasting glycemia slightly exceeded the acceptable norms and in Group IV ("PT+Cryo") the value of the parameter was at the upper limit.

After the therapy the results of the GLM analysis showed a statistically significant decrease in glucose levels for Group IV ("PT+Cryo") ($p = 0.02$). Furthermore, a downward trend in the discussed parameter ($p = 0.07$) was observed in Group II ("Cryo"). In Group III ("PT"), the study did not show significant changes in the level of glucose due to the applied therapy ($p > 0.05$).

The calculated indices of the lipid profile. i.e. TCh/HDL and LDL/HDL, did not differ significantly between the groups before the therapy ($p > 0.05$). Furthermore, no significant changes in these indices after the experiment were observed in any of the groups (see Table 2).

Table 2. TCh/HDL and LDL/HDL ratios before and after different types of therapy (mean value ± standard deviation)

	Before treatment				After treatment		
Group	I	II	III	IV	II'	III'	IV'
TCh/HDL	4.0±1.6 Cv = 0.400	3.5±1.1 Cv = 0.314	3.8±1.02 Cv = 0.268	4±1.3 Cv = 0.325	3.4±1.0 Cv = 0.294	3.8±1.0 Cv = 0.263	3.7±1.2 Cv = 0.324
LDL/HDL	2.5±1.0 Cv = 0.400	2.2±0.9 Cv = 0.409	2.4±0.9 Cv = 0.375	2.6±1.1 Cv = 0.423	2.1±0.9 Cv = 0.429	2.4±1.0 Cv = 0.417	2.4±1.0 Cv = 0.417

Cv – coefficient of variation
* pretest-posttest difference is statistically significant at the 0.05 level
** pretest-posttest difference is statistically significant at the 0.01 level

4. Discussion

The effect of cryotherapy on the body has been confirmed in numerous studies and encompasses changes occurring in various systems and organs, including the circulatory system, the nervous system, the

muscular system, the endocrine system, and the immune system [4, 23, 28, 29, 30, 31, 32, 33, 34]. Authors provide that during a cryotherapy session, the precapillary sphincters in the skin contract, which stops the precapillary flow, and thus, the oxygenated blood returns to large venous vessels and the right side of the heart. Next, during the stage called reactive hyperemia, the arteriovenous valves close, which increases the blood supply in tissues. Reactive hyperemia lasts for up to a few hours after the treatment [32, 35].

According to some authors, cryotherapy decreases muscle tension and increases the strength of muscles, which is the effect of reduced nerve conduction, pain, and reactivity of peripheral sensory and motor endings, and changes in the distribution of blood and nutrients [32, 35, 36]. Moreover, cryotherapy reduces the level of calcium in the blood serum, which is likely connected with the transfer of ions to the cellular space, which may improve fitness [37]. Skrzek et al. concluded that cryotherapy followed by physical exercises has a positive effect on bone turnover and the muscular functions in elderly women [20]. Sieroń and Stanek wrote that the reduction of pain due to cryotherapy is affected by the gate control mechanism (which filters the stimuli that come through to the CNS), a decrease in conduction speed of centripetal pain nerves, a reduction in muscle tension, and an increase in blood supply, which helps remove accumulated metabolites, lactates, and mediators of pain from the inflamed tissues and facilitates the supply of nutrients and oxygen [35, 36]. The increased level of anesthetic β-endorphins is also attributed to the pain-relieving effect [22]. The belief in these possibilities of cryotherapy, in particular its analgesic effect and the fact that it causes an improvement of the overall functioning of the body and quality of life, are the reason why this treatment is so popular among elderly women with osteoarthritis. Moreover, the effect of cryotherapy and kinesiotherapy may help reduce the need for painkillers and anti-inflammatory medicine. There is no data that would indicate whether cryotherapy also has a positive effect on the level of cholesterol and glucose in elderly persons, which parameters frequently have abnormal values.

Cholesterol is a chemical compound that is essential for the functioning of the body. It is transported in blood serum through lipoproteins. The simplest classification of lipoproteins distinguishes between LDL and HDL. LDLs transport around 60% of cholesterol and are responsible for the transport of cholesterol from the liver to tissues. In certain conditions, LDLs are also responsible for accumulation of cholesterol in the arterial walls, thus initiating the development of atherosclerosis. HDLs remove excess cholesterol from the cells and transport it back to the liver. The concentration of cholesterol in blood serum is changeable and shows numerous fluctuations connected with age. However, it is assumed that hypercholesterolemia more often occurs in old age [10, 14]. Many researchers indicate that disturbances of lipid metabolism, including the increase of the concentration of cholesterol in blood serum, are an important risk factor of the occurrence of atherosclerosis in cardiovascular disorders. The frequent occurrence of hypercholesterolemia concerns, first and foremost, the western countries and is consistent with numerous cases of cardiovascular disorders and death due to a cardiovascular event in these countries [10, 14, 15].

There are individual reports that confirm the beneficial effect of cryotherapy on the level of lipids in blood, including one publication that suggests the possibility of using it to prevent hyperlipidemia [13, 18, 24]. It was observed that 10 cryotherapy sessions caused a considerable beneficial reduction of the level of triglycerides, while a considerable decrease of the level of TCh, LDL, and triglycerides, and a considerable increase of the level of HDL was noted only after 20 cryotherapy sessions [18]. The present study lasted for only two weeks, which may be too short to cause changes in the lipid profile. Furthermore, the study focuses on the effect of low temperatures in elderly women, i.e. persons whose organisms, due to the changes in thermoregulation properties, may react to the cold in a different way than young persons.

During the exposure to low temperatures, the body strives to reduce heat loss and increases the production of metabolic heat. In young and healthy people, this is achieved mainly by using isolating properties of the fat tissue, vasoconstriction, and activating shivering and non-shivering thermogenesis. Authors write that in older people, these processes may be abnormal. The causes of limitation of the loss of heat involve the change in isolating properties of the fat tissue and a diminished reactive tone of cutaneous vasculature. Authors indicate reduced sympathetic vasoconstrictor responses during exposure to the cold. The diminished ability of aged skin to vasoconstrict concerns both the acral skin (e.g. feet,

hands, ears) and the nonacral skin (limbs and trunk) [38, 39].

Skin, as well as muscle vasoconstriction contribute to insulation from cold, so the impact of the diminished vasoconstrictor response on thermoregulation is aggravated by age-related loss of muscle mass. Moreover, resting and basal heat production diminishes 20% from the age of 30 years to the age of 70 years, which is connected to the loss of active muscle mass [40].

Furthermore, the decrease of muscle mass, as well as the reduction of metabolic activeness in elderly persons, causes a reduction of the shivering thermogenesis that leads to a limitation of the production of metabolic heat. Cold-induced metabolic heat production tends to be lower in older adults [41, 42].

The non-shivering thermogenesis connected with the activation of the brown fat is also impaired. The correct thermoregulation processes and physiological changes characteristic of exposure to low temperatures may, therefore, be impaired in a group of older people [43]. So it can be assumed that the reaction of the body to cryotherapy may also be weakened. This is confirmed by the results of the current study. No significant changes in the amount of total cholesterol, HDL, LDL, and triglycerides after 10 sessions of cryotherapy, were observed. Their mutual proportions, considered important for determining the risk of coronary heart disease, also did not change [44].

Many authors write that physical activity sensitizes the tissues to the effect of insulin, as well as increases the synthesis of proteins transporting glucose in muscle cells, which raises the efficiency of glucose uptake and the synthesis of glycogen. In persons with impaired glucose tolerance, regular physical exercise can delay diabetes or even prevent it completely [45]. Cryotherapy through numerous. abovementioned physiological changes connected with lowering the temperature of the skin and initiating thermoregulation mechanisms, may increase glucose uptake by the tissues in order to produce heat [42].

Teległów et al. observed that in young healthy men, the level of glucose in the blood decreased significantly after two months of regular cryotherapy [46]. In turn, the research by Lubkowska et al. did not showed any significant decrease of this indicator after either 10 or 20 sessions of cryotherapy [18]. The current study revealed a significant decrease in the concentration of glucose in the blood of individuals from the group participating both in cryotherapy and kinesiotherapy. Therefore, it can be concluded that cryotherapy and kinesiotherapy both had an important effect. It is only the application of the two stimuli together that can effectively cause changes in the discussed parameter.

5. Discussion

Applying whole-body cryotherapy, kinesiotherapy and cryotherapy combined with kinesiotherapy in older women with spondylarthrosis do not cause changes in the level of cholesterol and triglycerides. It seems that two weeks of cryotherapy cannot be considered as a method of reducing hypercholesterolemia in this age group. Cryotherapy combined with kinesiotherapy may cause changes in blood glucose levels.

6. Limitations of the adopted research methodology

Performing a full evaluation of the effect of cryotherapy on the selected blood parameters would require additional measurements some time after the series of cryotherapy treatments. The possibility of the occurrence of adaptational changes in the level of cholesterol or glucose as a delayed action response cannot be excluded. Moreover, the studied patients' diet and the medicine they take should also be taken into account as a factor affecting the patients' lipid profile, and the BMI of the control group should be taken into account in the analysis of the between-group differences.

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